Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 | SEPTEMBER 1951 | No. 9

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AND THE *Journal of the Southern California Meter Association*

Los Angeles Harbor Steam Plant

Photo courtesy Taylor Instrument Companies

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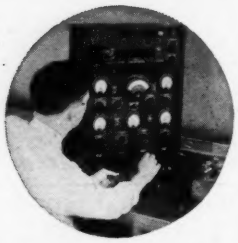

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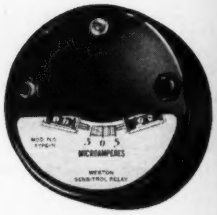

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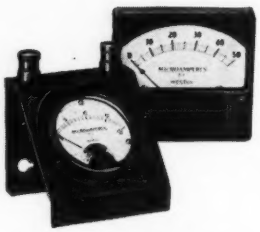

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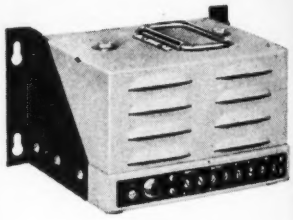

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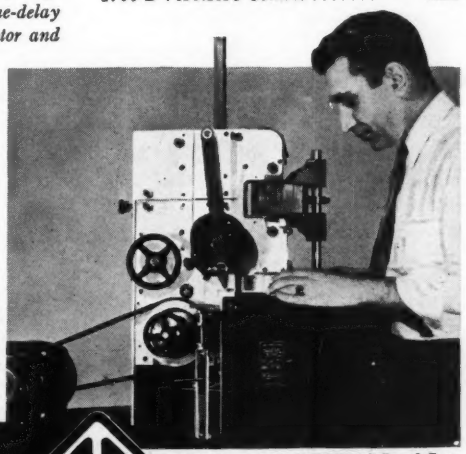

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Measurement of Flow of Fluids through Orifice Meters (Conclusion) 1101
By William L. Cowan

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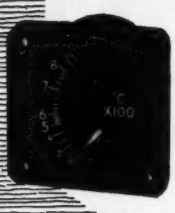

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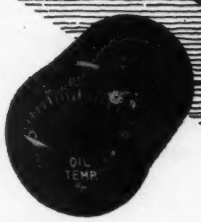

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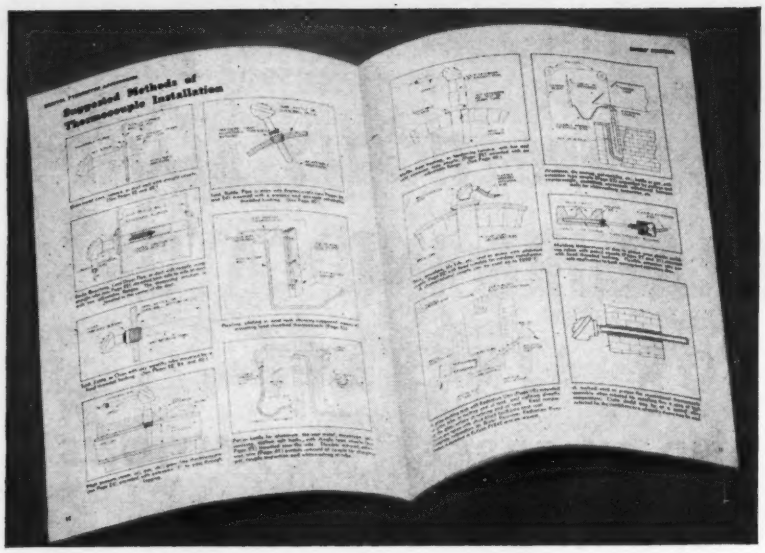

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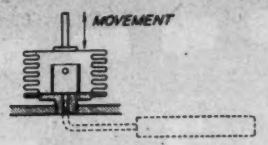

Fig. 1 Thermostatic Motor—This type of assembly is widely used in temperature regulators, etc., where a thermostatic charge is confined in the bellows and where a valve, switch, damper, etc. is to be operated in response to temperature changes.

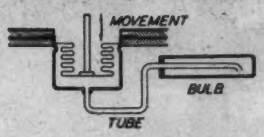

Fig. 2 Thermostatic Motor—This assembly is used where it is desirable to have the thermostatic charge confined outside the bellows and within a cup. May be used with or without remote bulb shown.

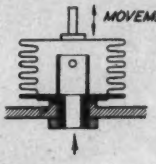

Fig. 3 Pressure Motor—Bellows assemblies are often employed to convert pressure effects into controlled movement. Fig. 3 shows such an assembly where the pressure is applied inside the bellows.

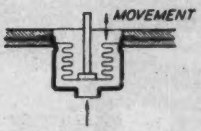

Fig. 4 Pressure Motor—This assembly differs from Fig. 3 in that the pressure is applied outside the bellows and within a cup.

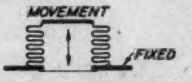

Fig. 5 Expansion Chamber—This type of assembly is employed to absorb thermal or pressure expansion. With suitable heads, it would be used to serve as a reservoir for a liquid or gas. Example: Oil reservoir for electrical cable joint.

Fig. 6 Expansion Joint—Packless and leakless construction for expansion joints used to absorb thermal expansion of pipe lines carrying steam, water, etc. May be used to absorb vibration and provide flexible connection for other applications.

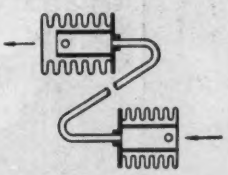

Fig. 7 Motion Transmission—Two bellows assemblies joined by a tube for hydraulic transmission of motion or power. Motive force applied may be either thermostatic or mechanical.

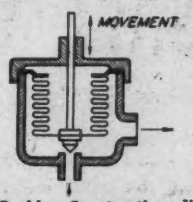

Fig. 8 Packless Construction—Illustrating packless valve construction. Same principle used to seal stem movement or adjustment in many types of apparatus.

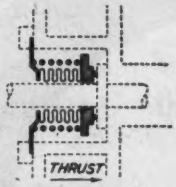

Fig. 9 Shaft Seal—Widely used for refrigeration compressors to prevent leakage around revolving shaft. Spring pressure holds nose of seal against shoulder on shaft. Another type used rotates with shaft and seals against stationary plate.

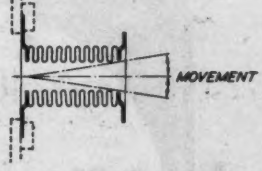

Fig. 10 Flexible Joint—Providing a means to seal a flexible joint or mechanical movement of levers, linkage, etc., against leakage where the movement must be conveyed outside an enclosure. Example: Operating stem of float switches, etc.

TEMPERATURE CONTROLS

FULTON SYLPHON
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Knoxville 4, Tenn.

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Westinghouse Switchboard Instruments are available in circular or conventional scale types for any switchboard application.

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You get a wider selection for every need whether it be a-c or d-c current and voltage, single or polyphase circuits, watts or vars, frequency, power factor, synchroscopes, temperature indicators, ground detectors or synchrotie (position indicators). And you get . . .

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Westinghouse Instrument Application Engineers are available to consult with and serve you in selecting and applying the proper instruments for your application. Simply call your nearest Westinghouse office.

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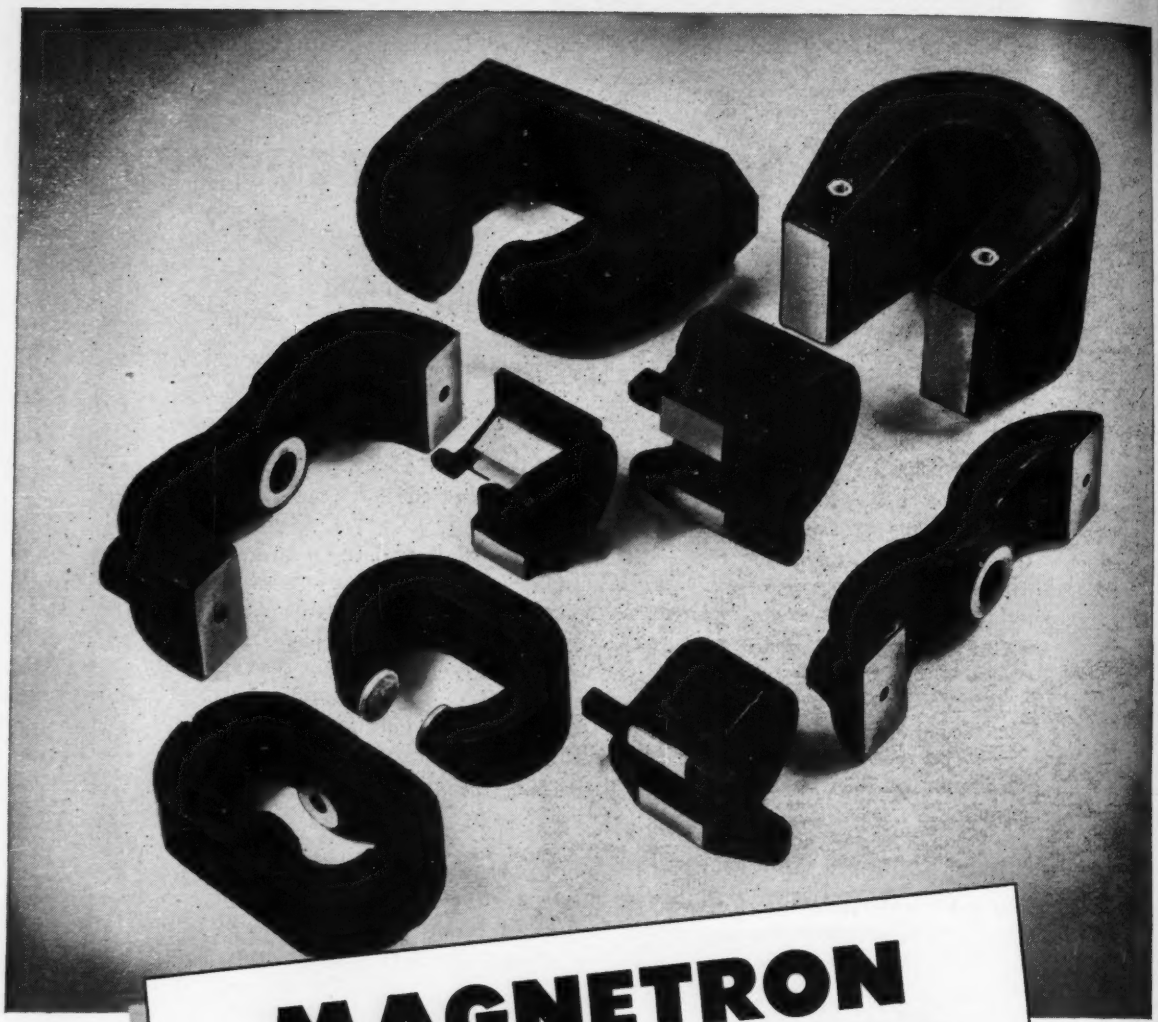
YOU CAN BE SURE... IF IT'S Westinghouse

INSTRUMENTS



MAGNETRON
PERMANENT MAGNETS AND ASSEMBLIES

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Complete assemblies with Permendur, steel or aluminum bases, inserts and keepers as specified. Magnetized and stabilized as required.

THE ARNOLD ENGINEERING COMPANY

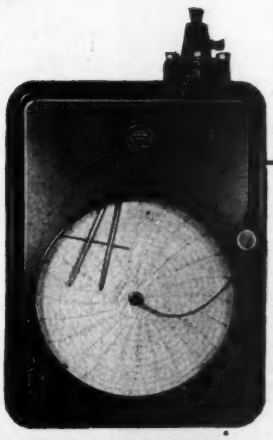
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

PRESSURE TIGHT WITHOUT LUBRICATION

- NEW TEFLON-SEAL STUFFING BOX
- CUTS METER MAINTENANCE
- ELIMINATES LEAKS
- ELIMINATES SHAFT FREEZING

STANDARD IN 1800 PSI ORIFICE METERS



Teflon-Seal Stuffing Boxes have been operating for more than two years without servicing in thousands of orifice meter installations! Applications such as sour gas, wet gas, caustic solutions — almost every conceivable service — have failed to impair meter operation. Maintenance problems are drastically reduced or eliminated!

The Teflon-Seal bearing is pressure-sealing around a precision made, centerless-ground Monel metal shaft, *without grease* and *with minimum friction*. All other stuffing box parts are corrosion resistant stainless steel. The Teflon-Seal Stuffing Box is suitable for ambient meter temperatures to 150°F. and working pressures to 1800 psi. Units are adaptable to older types of orifice meters now in service.

Here is another example of American Meter Company's policy of constant product improvement to uphold a century-old tradition of "*Sustained Accuracy at Lower Cost.*"

See our display, booth 101-5, Sixth National Instrument Exhibit, Sam Houston Coliseum, Houston, Texas, September 10-14.

PROPERTIES OF TEFLON

Teflon (polytetrafluoroethylene) is a synthetic polymer with the following properties: low coefficient of friction — zero water absorption — high impact strength — toughness — form stability — and exceptional chemical inertness. It retains strength at temperatures from —100°F. to 550°F. and does not stick or "weld" to other materials. It resists the attack of all known solvents except molten alkali metals, with no change in weight or properties.

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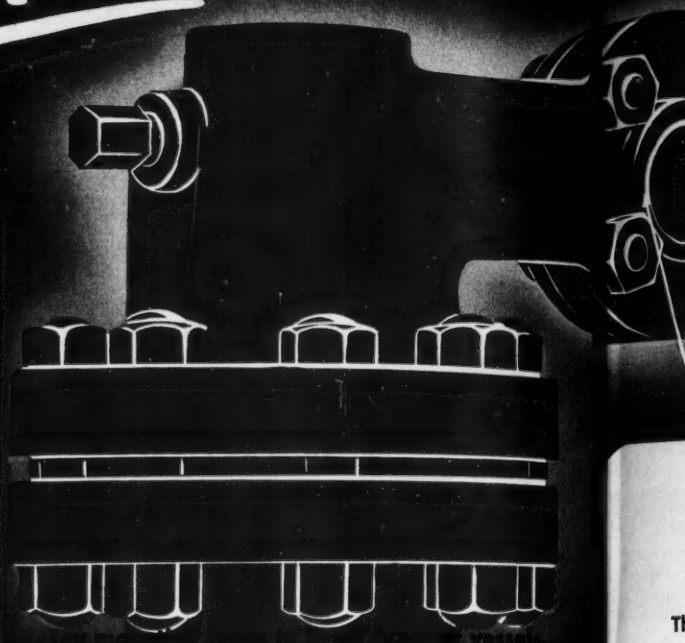
AMERICAN METER COMPANY
INCORPORATED ESTABLISHED 1836

Look at the Whole Picture...



WHEN SELECTING LEVEL CONTROLLERS

Use the C_Q Method—Evaluate All the Quality Factors

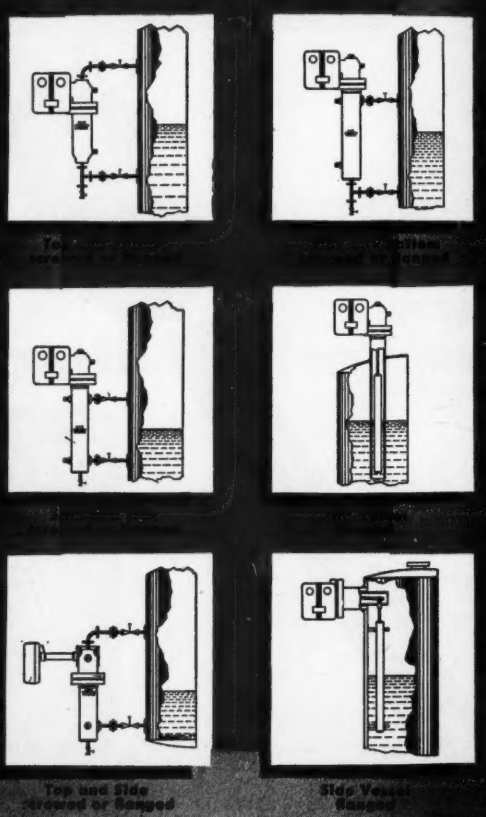
One well designed and manufactured part does not make a level controller that will "provide accurate performance over a long period with a minimum of maintenance and operation delays." *Every* part must be designed and manufactured so that all combine to make a controller which incorporates wise selection of materials for the intended service; skillful design for accurate operation; and experience which forestalls the difficulties you are likely to encounter in the field.

So in selecting level controllers, use the C_Q Method — evaluate *all* the quality factors in relation to your standards. The sum of the value of all these factors is the C_Q (Quality Coefficient). A product with a high C_Q will give you the performance you have a right to expect. And in considering price, don't forget the over-all cost* is lowest for a high C_Q product. For comparison purposes — among comparably priced controllers

$$\text{Real Cost} = \frac{\text{Price}}{C_Q}$$

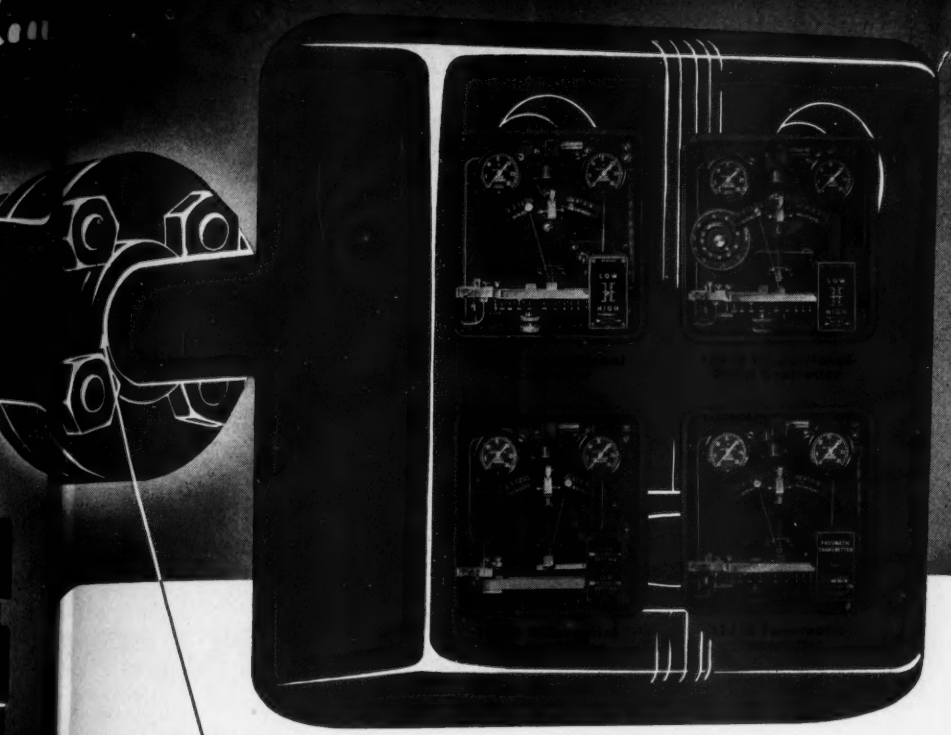
Look at the whole picture — use the C_Q Method — evaluate *all* the quality factors.

**Purchase price plus cost of maintenance and down-time.*



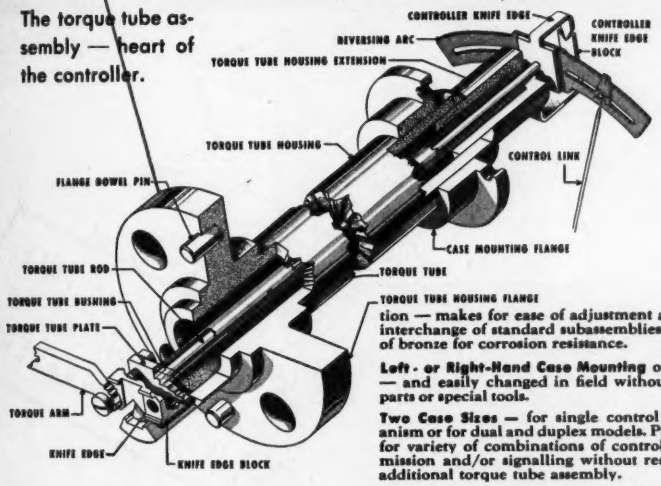
THE MASONEILAN 12000 SERIES LEVEL CONTROLLERS

A High C_Q Product



Three Standard controller types and the transmitter (also pneumatic switch) in the standard case; dual or duplex combinations of these in a larger case.

The torque tube assembly — heart of the controller.



Note the Quality Factors of the Masoneilan 12000 Series Level Controllers

Sturdy Instrument Case with ribbed reinforcements to prevent distortion due to temperature and handling which might create inaccuracy in control mechanism. Aluminum with Weatherproof finish and Gasketed door — protect against effects of weather and corrosive atmospheric conditions.

One Piece Air Manifold eliminates much of air piping inside case — simplifies construction — makes for ease of adjustment and for interchange of standard subassemblies. Made of bronze for corrosion resistance.

Left- or Right-Hand Case Mounting optional — and easily changed in field without extra parts or special tools.

Two Case Sizes — for single control mechanism or for dual and duplex models. Provides for variety of combinations of control transmission and/or signalling without requiring additional torque tube assembly.

Large Capacity Relay-type Pilot: Design insures instant response to variations in nozzle pressure. Includes metering tube for constant nozzle supply. Fastening directly to manifold avoids air piping. Uses minimum air supply.

Simple Proportioning Mechanism: Minimum number of parts, simplified linkage, use of proportional leaf spring — insure instantaneous response. All adjustments simple, with clearly visible scales. Action reversible by one simple adjustment. Proportional band setting independent of specific gravity; scale provides wider graduation spacing in lower settings; causes minimum upset to process because alignment spring, leaf spring and proportional bellows forces in equilibrium at midpoint of output pressure range. Simplified linkage and flexure bearings eliminate lost motion.

Automatic Reset Mechanism: Adds reset response to proportional response. Simple unit adjustable over spiral scale with wider graduation spacing in lower reset rate settings.

Differential Gap Mechanism: Substitutes proportional on-off action for standard proportional action. Provides for adjustable gap between high and low limits.

Selection of Supplementary Functions: Design provides for pneumatic transmitter, pneumatic or mechanical signal switch using same torque tube and displacer assemblies.

Dual and Duplex Types: Selection of combinations of control mechanisms, controller plus transmitter, controller plus switch, etc. — in *one case*; using only *one torque tube assembly*.

Simple Mechanical Indicator inside case provides serviceman with reliable, direct indication of level; has no complicated linkage — requires no field calibration.

Torque Tube Assembly design provides
(a) selection of materials — inconel, monel, stainless steel, bronze.

(b) all parts of torque tube subassembly of same alloy — avoids contamination of the weld.

(c) fabrication by latest type inert arc welding equipment and methods.

(d) knife-edge bearing at each end insures true center of rotation — cannot be off-centered by high temperature or practical tolerances in fabrication — eliminates objectionable friction.

(e) Torque tube length, wall thickness and diameter selected for most desirable combination of low operating stress and load carrying ability.

Displacer Hanger has modified knife-edge bearing at connection to torque arm. Integral or detachable extensions available for internal mounted displacers.

Displacers made of stainless steel tubing; designed so that standard control mechanisms may be used without modification, for all applications.

Selection of Mounting Types available to meet all vessel requirements. Choice of 9 Level Ranges between 14" and 15 ft. (standard). Special ranges may be supplied.

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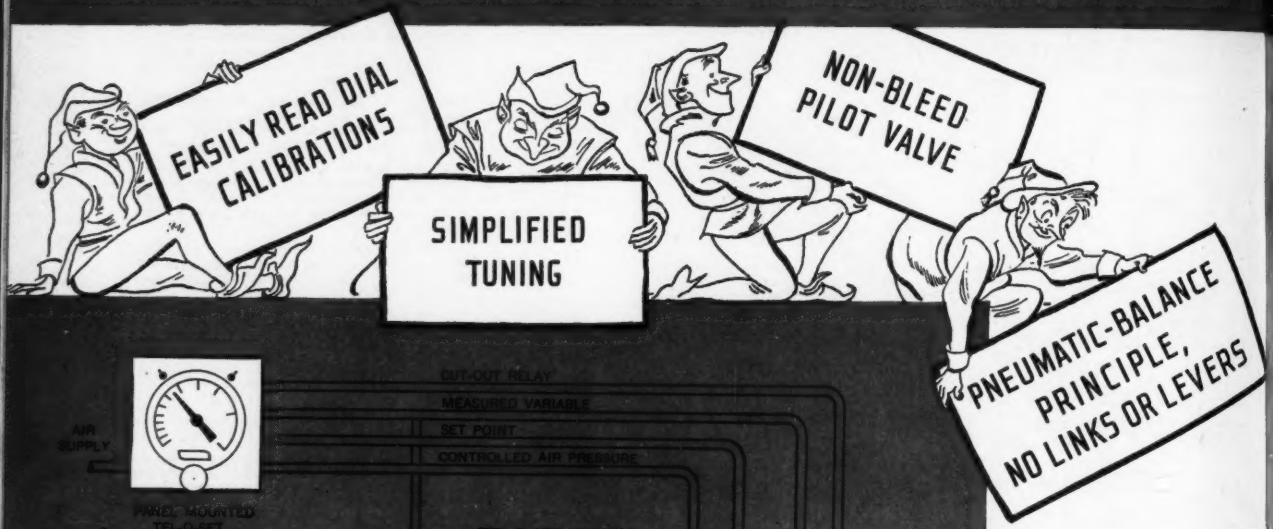
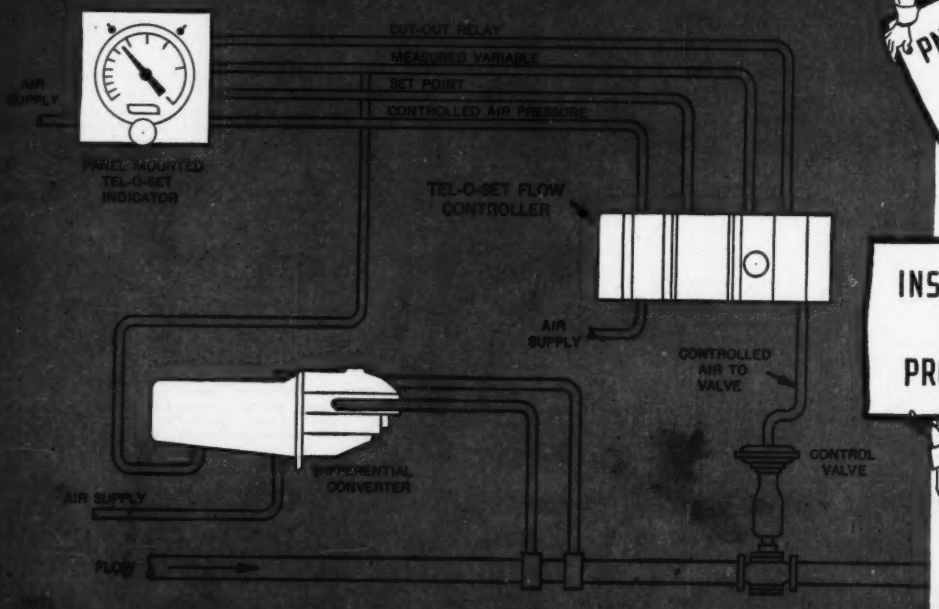
Mason-Neilan Regulator Co., Ltd., Montreal and Toronto

Important Contribution

Introducing...

The New TEL-O-SET CONTROLLER...





ENGINEERED CONTROL SYSTEM FOR FLOW

The Tel-O-Set Controller pictured in this diagram is one unit of the family, each part designed and built as an engineered, integrated loop.

INSTANT RESPONSE TO PROCESS CHANGES

to Process Control

- **FOR ALL CONTROL APPLICATIONS —**
  Flow, temperature, pressure level and other process variables.
- **FOR GREATEST ECONOMY IN APPLICATION —**
  Three control forms available.
- **FOR OPTIMUM FLEXIBILITY —**
  Universal bracket for control room, valve yoke or structure mounting.
- **FOR EASY MAINTENANCE —**
  Coded, interchangeable sections. Split manifold permits removal of controller while on manual by-pass.

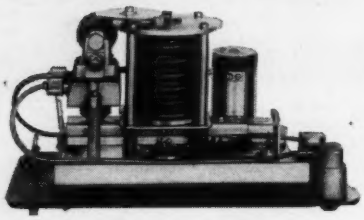
For detailed information, write for a copy of Specification Sheet No. 768 . . . and call in our local engineering representative for a discussion of your process needs.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

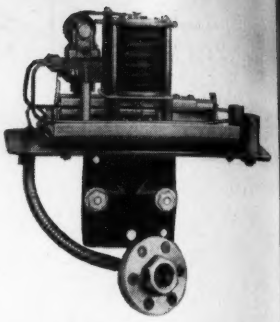
MINNEAPOLIS
Honeywell
Brown Instruments

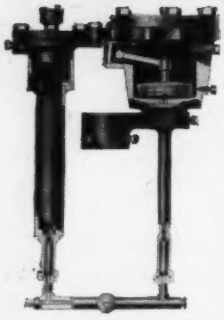
H HONEYWELL

MEASURE

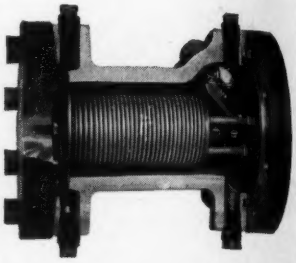


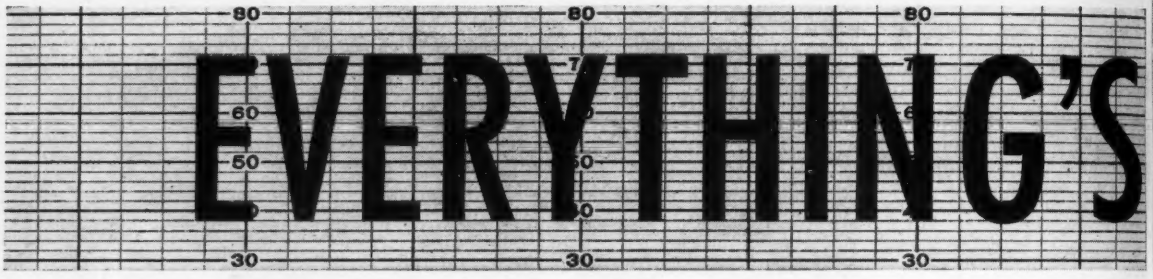
Taylor TRANSAIRE* Transmitters virtually eliminate time lag in measuring and transmitting smallest temperature and pressure changes. Temperature model (*left*) has derivative action, SPEED-ACT*, in measuring circuit, which assures dynamic accuracy under changing conditions. Pressure model (*right*) will detect changes of 1/10 of 1% of the range span, accurate to 1/2% of span rather than pressure level. Temperature and barometric compensation assure consistent accuracy.



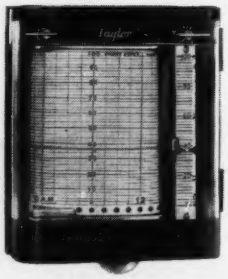


Taylor Differential Pressure Manometers give accurate, dependable measurement of flow, liquid level and specific gravity. Mercury model (*left*) is accurate to ½ of 1% of the range, has interchangeable tubes for continuous ranges from 10 to 500 inches of water. Aneroid (mercuryless) models (*right*) of 300 and 1500 psi working pressures. Range limits: 0 to 20″ to 0 to 500″ water. Also available in all-316 stainless steel for corrosive mediums.



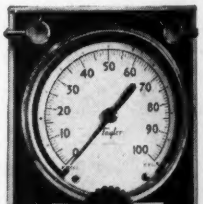


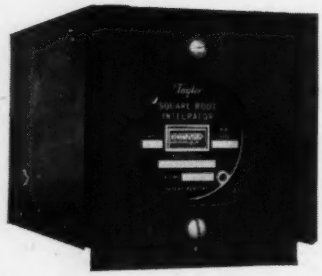
RECEIVE



The TRANSET Recorder (*left*) has automatic-manual unit, remote set-point adjustment and valve position indicator. Takes only 4⅜″ x 5″ panel space, gives a continuous 30-day linear chart record, with 3 hours visible. Electric or pneumatic chart drives.

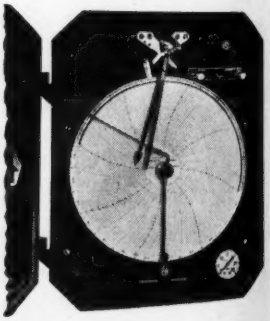
The TRANSET Indicator (*right*) has all the features of the TRANSET Recorder, but gives no chart record. Easy reading 3½″ dial, mounts in same size panel opening as TRANSET Recorder.



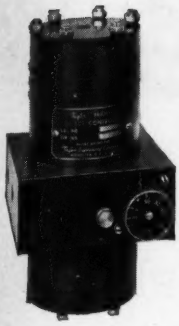


TRANSET Receiving Flow Integrator (*left*) also takes just 4⅜″ x 5″ panel space. It totals the flow of liquids and gases, is available in square root or linear forms. Like the other TRANSET Receivers, its small size makes it ideal for graphic panels.

Taylor 84JF Recording Receiver (*right*) is an alternate part of the TRANSET System designed for those who want matching cases on conventional panel boards. Has all the features of the small TRANSET Recorder, but utilizes standard 12″ circular charts.

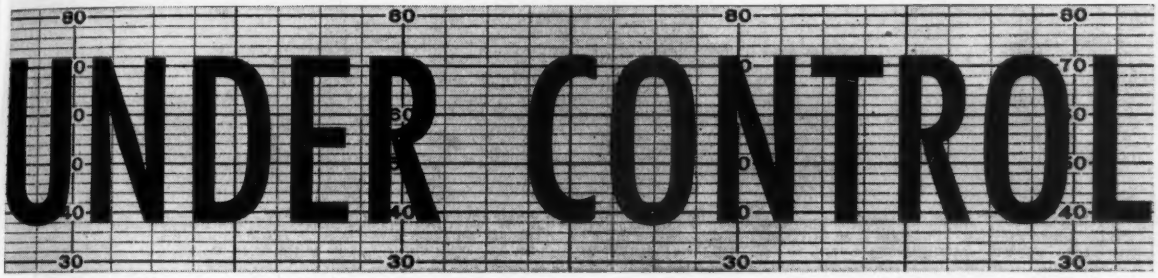


CONTROL



The TRI-ACT* Controller (*right*) is a force-balance pneumatic controller with a new circuit embodying three control responses: proportional, PRE-ACT* (rate action) and automatic reset. Gives precise control never before believed possible, with faster, more stable recovery on load changes, no overpeaking on start-up. Can be locally or panel mounted.

BI-ACT* is TRI-ACT's little brother. The BI-ACT Controller (*left*) is a lower cost instrument with *two* control responses, proportional and automatic reset, both adjusted with *one* stability knob. It's the ideal instrument for dependable, accurate performance on those applications where the quality of control obtainable with derivative response is not essential.



with Taylor's TRANSET System regulating any process variable*

*Trade-Mark

THE ANSWER to almost any industrial control problem is on these pages. Taylor's New TRANSET Control System can control practically any process variable, with a precision never before possible.

A wide variety of units available within each of the system's three steps, measuring, controlling and receiving, makes TRANSET Control adaptable to fit your control requirement perfectly. Each unit incorporates brand-new features and techniques, and the units in each step are designed to take fullest advantage of the superior performance of units in the other steps. It's an unbeatable team that can cut costs and improve product quality in any process industry.

For full information on how you can profit from Taylor TRANSET Control, ask your Taylor Field Engineer, or write for **Bulletin 98097.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

Instruments for indicating, recording and controlling temperature, pressure, flow, liquid level, speed, density, load and humidity.

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ACCURACY FIRST
SINCE 1851

Taylor Instruments
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY

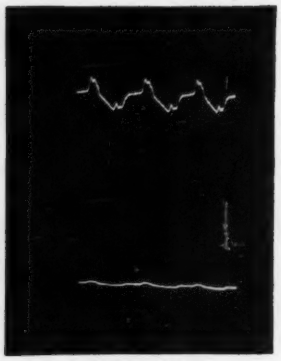
Where "Photographic Memory" Counts!

When you're comparing waveshapes it takes the "photographic memory" of a camera to give you the whole story in accurate, permanent form.

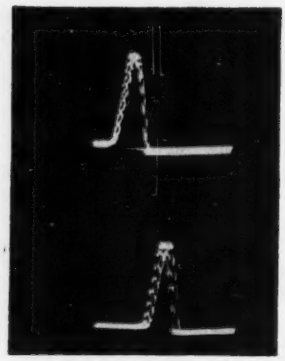
Until recently, photographic oscilloscope recording called for considerable trouble in setting up equipment and a long time period for developing the results. But today, with the Fairchild-Polaroid Oscilloscope Camera, it's an easy job to record as many traces as are needed.

Take a look at the prints below. They provided the engineer with valuable but inexpensive records for immediate evaluation. All were removed from the camera *one minute* after the final exposure was made.

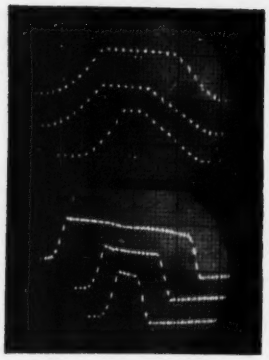
The stories of 3 "One Minute" Oscillograms



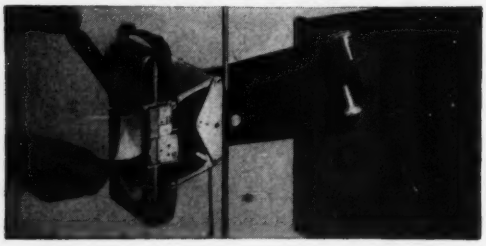
1. BEFORE AND AFTER. A visual comparison of "before and after" conditions is an easy job for the "one step" camera. Here, the upper trace shows the output of a full wave rectified power supply with insufficient filtering. The lower trace shows the effectiveness of the addition of a filtering condenser. The camera is easily adjusted to two positions (upper and lower) for two exposures; traces are exactly one half scope size.



2. SUPERIMPOSING FOR COMPARISON. The problem—determine the maximum time-interval variation between successive camera shutter openings and flash circuit closings. Instead of carefully measuring successive scope traces, the engineer superimposed several exposures for easy comparison. The length of the trace before the shutter opened is a measure of the time between the electrical contact closing and camera shutter opening.



3. MULTIPLE EXPOSURE PRE-SOLARIZATION. Here, by making 3 successive exposures on each half of the print, the engineer was able to record performance of a camera shutter at its 1/100, 1/200, 1/400 second (upper) and 1/25, 1/50, and 1/100 second settings (lower). "Pre-solarizing," the process of pre-exposing the print with the trace off the screen, made it possible to record the high writing speeds involved.



A minute after you've pulled the tab a finished print is ready for evaluation.

for still or *continuous-motion* oscilloscope recording on 35-mm film or paper

—THE FAIRCHILD OSCILLO-RECORD CAMERA

The Fairchild Oscillo-Record Camera is the first unit specifically designed for the purpose of recording cathode-ray tube images. Features: records still or continuous motion on standard 35-mm film or paper, film footage indicator, electronic speed control — 1 to 3600 in./min., film capacity — 100, 400 or 1000 feet.

SPECIFICATIONS

Lens and Shutter—Choice of 75mm f2.8 Wollensak Oscillo-Anastigmat with #2 Alphax shutter having speeds of 1/25 sec. to 1/100 sec., "time" and "bulb"; or, 75mm f1.9 Wollensak Oscillo-Anastigmat with #3 Alphax shutter having speeds of 1 sec. to 1/100 sec., "time" and "bulb".

Picture Size—3¼ x 4¼ in. (2 or more images per print; 16 exposures per roll of film.)

Image Size—One-half reduction of scope image.

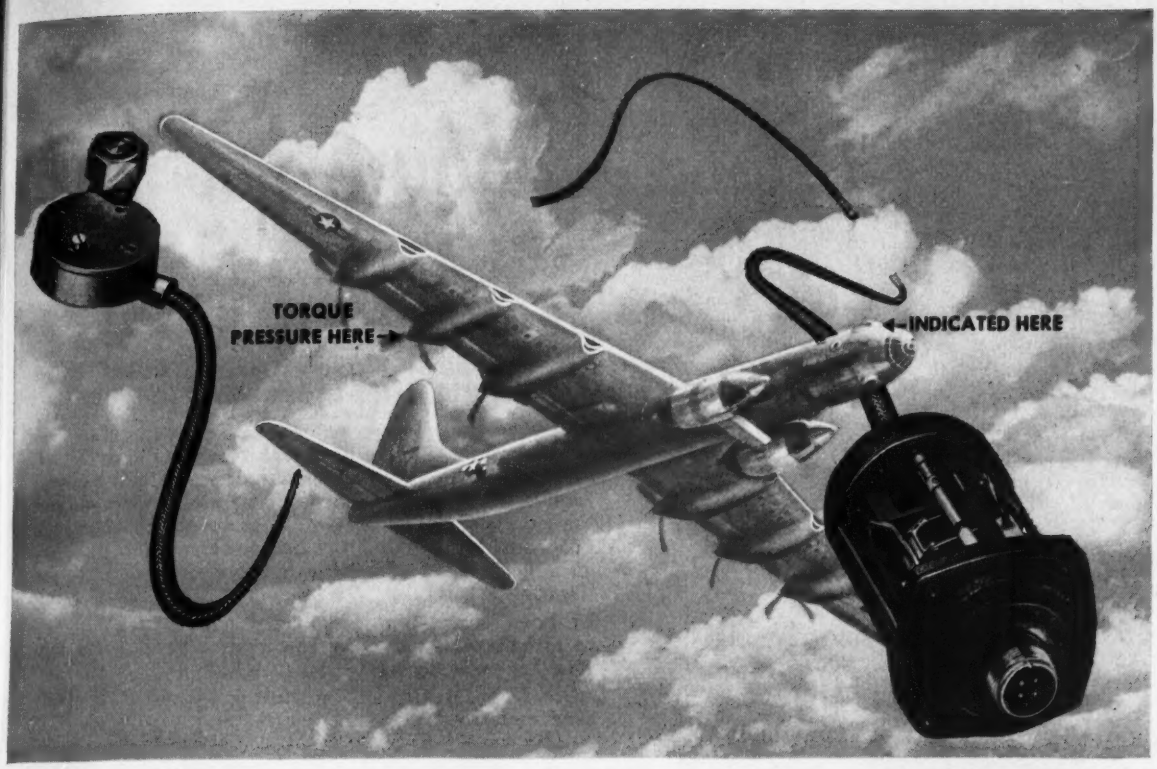
Writing Speed—With f2.8 lens, up to 1 in/μsec at only 3000V accelerating potential; higher speeds at higher voltages. With f1.9 lens these values are approximately doubled.

Dimensions—Camera, 10½ x 5¼ x 6¼ in.; hood, 11 in. length, 7½ in. dia; adapter, 2 in. width, 6⅝ in. max. dia.

Weight—Complete, 7¾ lb.

Fairchild-Polaroid Oscilloscope Camera Kits include camera, carrying case and film. Write today for complete data on the Fairchild-Polaroid and Fairchild Oscillo-Record Cameras. *Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y. Dept. 120-15Fl.*

FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS



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Provides complete freedom from the attacks of sand, dust, fungus, salt fog and humidity

LOOK AT THESE EXCITING "FIRSTS" . . .

- Hermetically sealed and helium protected pressure and electrical elements.
- Nispan "C" pressure elements eliminating bimetallic compensation.
- Higher precision in remote transmission.
- Smaller and lighter in weight with tear-strip ease of disassembly.
- External adjustment through hermetic seal.
- Isolating link and pressure pick up for temperature extremes of —85 and +230 F.

In this Synchro Torque Pressure Transmitter one element measures the pressure and the other the ambient outside pressure. Together, these two Nispan elements measure the applied pressure in a sealed case charged with an inert gas, and transmit an electrical signal through a glass-to-metal connector.

This refreshing solution to a difficult problem leads a whole flight of new direct-connected clamp-on pressure indicators for oil, fuel, manifold, and hydraulic pressures.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

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...Digging for facts

ON AUTOMATIC REGULATING VALVES?

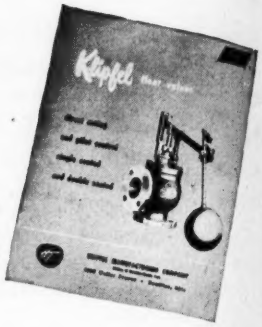
YOU'LL FIND THESE KLIPFEL BULLETINS PRACTICAL, FACTUAL AND USEFUL!

Klipfel engineers have put a lot of experience and research into these bulletins to make them useful to you... the man who uses or specifies automatic regulating valves. Each bulletin covers such points as: the advantages and limitations of different valve constructions; selecting the proper type valve for given operating conditions; determining the most effective and economic size valve for the job.

In short, Klipfel engineers have prepared these bulletins to assist you in selecting the type and size valve best suited to your needs.

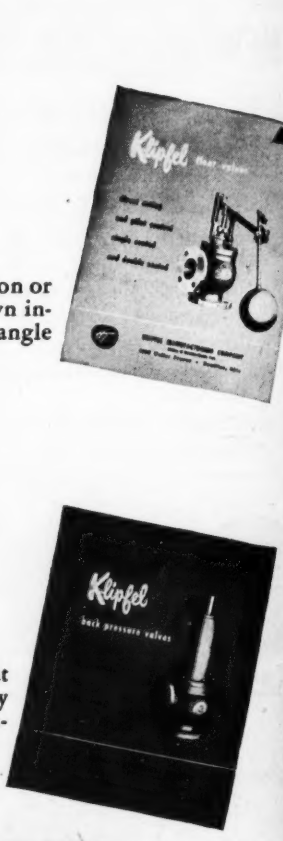
Write Dept. DA9 for any bulletins you wish. We'll gladly send them to you.

KLIPFEL REDUCING VALVES
for steam, air and water . . . in lever and weight, air loaded, pilot control and spring loaded types; descriptions, illustrations and complete selection data in Bulletin 148.



KLIPFEL FLOAT VALVES
Single and double seated types with direct action or pilot control for remote location. Types shown include quick-acting valves; all are available in angle and globe patterns. Bulletin 349.

KLIPFEL THERMOSTATIC VALVES
vapor pressure operated valves with spring or weight and lever loading. Valves are ball type, balanced cup and disc or balanced inner valves. Min. temp. 80°. Max. temp. 250°. Range limit of any instrument 40°. Full data in Bulletin 449.



KLIPFEL BACK PRESSURE AND RELIEF VALVES
for control of air, steam and water pressures at the valve inlet in various types for practically any service. Bulletin 648 gives complete details including dimensions and capacities.

Klipfel VALVES INCORPORATED

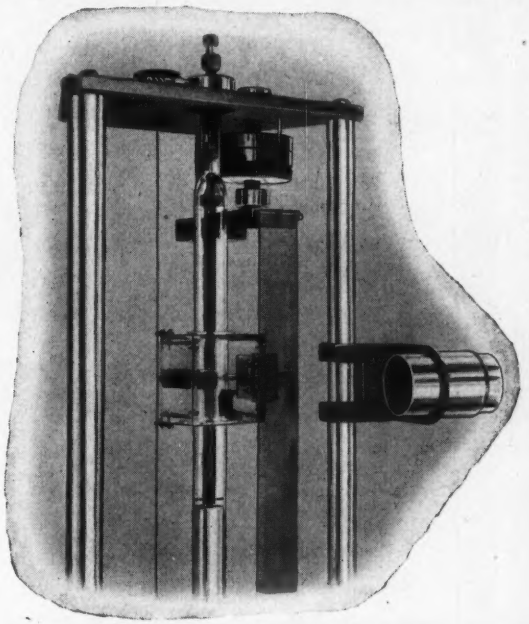
DIVISION OF HAMILTON - THOMAS CORPORATION, HAMILTON, OHIO

PRECISION PRESSURE CALIBRATION

introducing

THE W&T PRECISION CALIBRATING STANDARD

The new W&T Precision Calibrating Standard offers an accurate and convenient means for measuring either absolute or differential pressure. Consisting of a mercury column designed for convenient bench mounting it provides a custom calibrated range of 800 mm. Hg. in any desired units. For precision calibrations, readings to 0.01 mm. mercury with an accuracy of 1 part in 5000 are made possible by a unique magnetic vernier. Dependable and consistent results allow for its use in the calibration of such pressure sensitive instruments as aircraft altimeters, surveying altimeters, meteorological barometers, laboratory barometers and for absolute pressure elements having a controlling or telemetering function.



Outstanding features of the W&T Precision Calibrating Standard include:

Range of Absolute or Differential Pressure:	0 to 800 mm. Hg. by 1 mm. or any other units
Magnetic Vernier Graduation:	One-tenth scale graduation
Accuracy:	1 part in 5000

Built-in Thermometer

Temperature and gravity compensated scale

Full-range indication

Filtered pressure inlet

Meniscus reading eliminated

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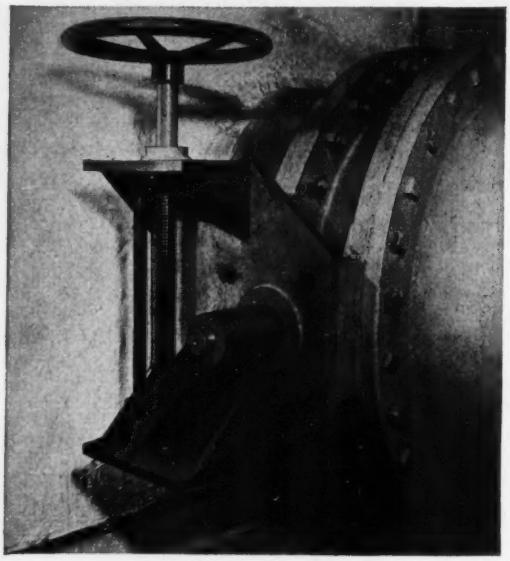
R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



RUGGED Simplicity

Correctly engineered mechanically and metallurgically, all body assemblies of R-S Valves equal or exceed A. S. A. standards in every detail. These valves are designed and constructed for rugged service and provided with such safety factors that they will exceed service expectations as well as reduce pumping and blower costs.

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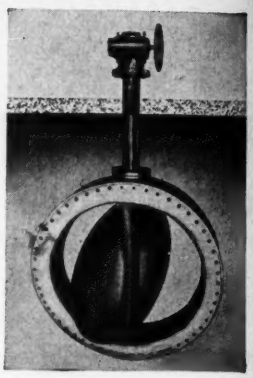
4600 Germantown Avenue, Philadelphia 44, Pa.
An S. Morgan Smith Company Subsidiary

R-S VALVES simplify the Control and Shut-off of Volume and Pressure from 2 to 2500 psig. Write for catalogs 17 and 18.



No. 739-740—Sixty-inch, 50-pound Heavy Duty Valve with gear reduction drive and handwheel for handling water at 40 psig. Vertical valve stem enclosed in steel pipe support. Thrust bearing absorbs vertical load.

No. 730—R-S Heavy Duty Floor Stand for rugged service in connection with any standard R-S handwheel operated valve.

No. 767—A 3-Way Valve (Two 24-inch 125-pound Cast Iron Valves bolted to 125-pound American Standard Tee). Electric motor operated by cross linkage. Automatic declutching handwheel for emergency operation.

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INCORPORATED (ESTABLISHED 1836)

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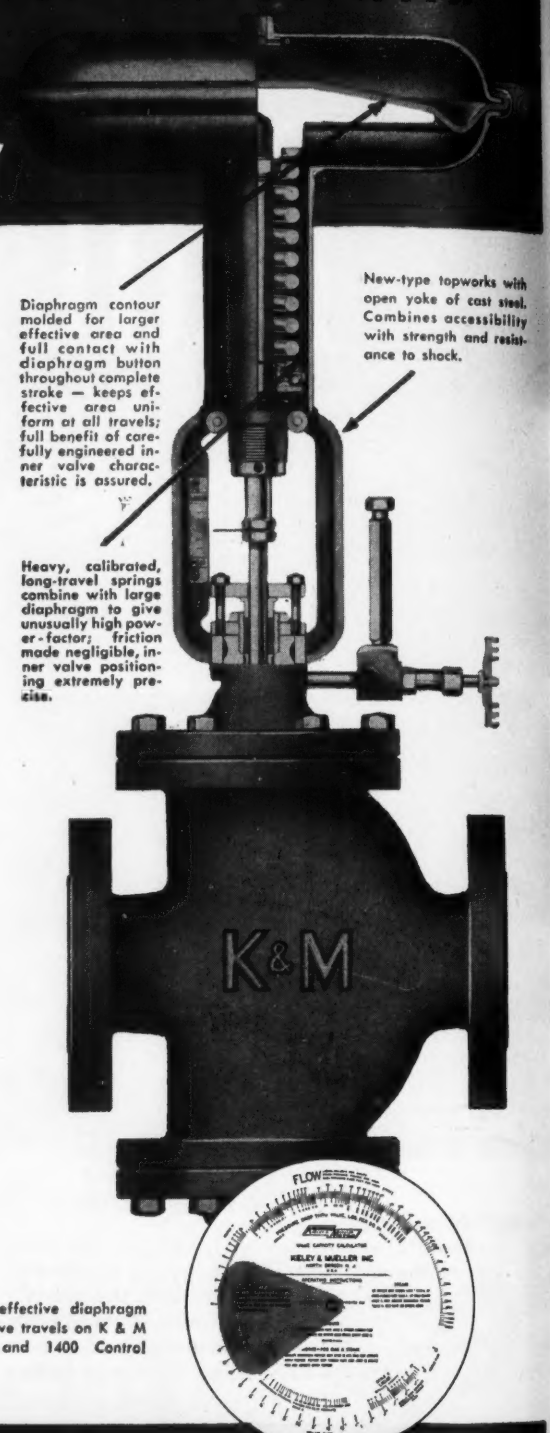
GREATER POWER *for* GREATER ACCURACY

The Diaphragm Motor of the far-advanced K & M Control Valve is designed for the more exacting needs of modern process industries. An unusually high power-factor is obtained by the carefully-engineered relationship of large effective diaphragm area and heavy, calibrated spring; friction is negligible, inner valve positioning more precise. The diaphragm is specially designed for constant affinity with the button contour; this assures a uniform effective area throughout the complete valve stroke, thus more uniformly accurate control. The unusually large area of the diaphragm in relation to the valve size also helps assure more precise control.

K & M motors are available for direct action or reverse action without change in effective area or stroke.


Diaphragm contour molded for larger effective area and full contact with diaphragm button throughout complete stroke — keeps effective area uniform at all travels; full benefit of carefully engineered inner valve characteristic is assured.
New-type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.
Heavy, calibrated, long-travel springs combine with large diaphragm to give unusually high power-factor; friction made negligible, inner valve positioning extremely precise.
K&M
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KIELEY & MUELLER INC

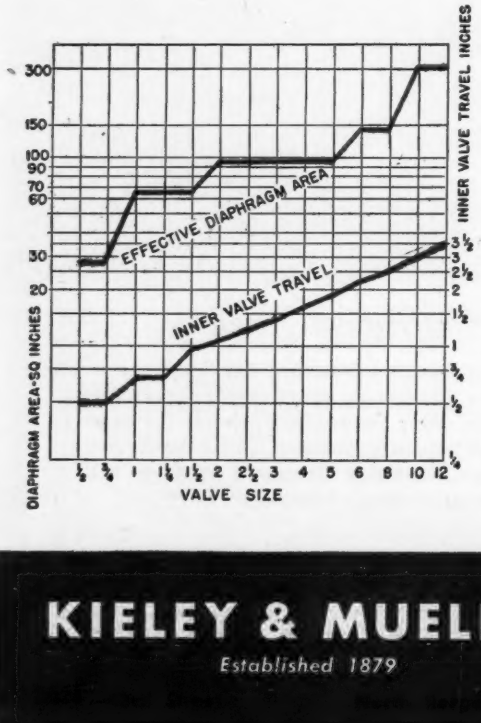


Chart shows effective diaphragm areas and valve travels on K & M Series 1200 and 1400 Control Valves.

KIELEY & MUELLER

Established 1879

What's wrong with telephone WU 2-1186?

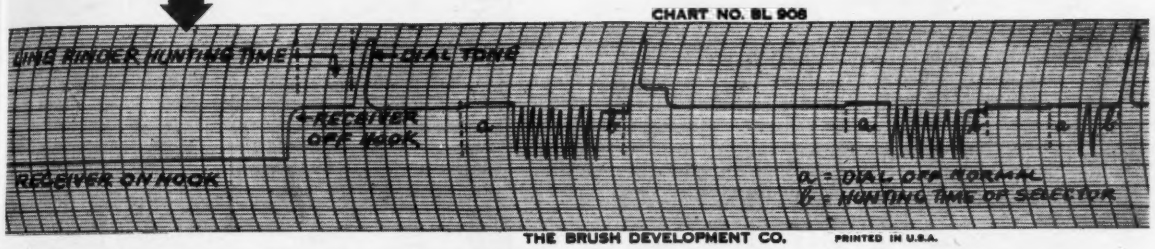
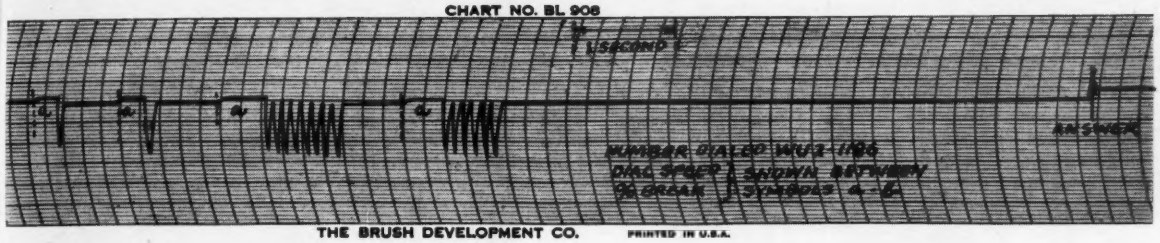


CHART NO. BL 908
RECEIVER ON HOOK
RECEIVER OFF HOOK
a = DIAL OFF NORMAL
b = HUNTING TIME OF SELECTOR
THE BRUSH DEVELOPMENT CO.
PRINTED IN U.S.A.



Fast relays checked by BRUSH Analyzer

A Brush Analyzer drew the graph above when one of the subscribers of an eastern telephone company picked up his phone and dialed WU 2-1186.

This record—drawn automatically in the time it took to dial the number—shows the timing and magnitude of every electrical impulse involved in the complex operation. Such records of impulses from the dials of both subscribers and operators provide the tip-off on equipments which require adjustment or repair.

This check on fast relay operation is but one of hundreds of investigations of electrical and mechanical phenomena which are being made speedily with Brush Analyzers. They record instantaneously. They simplify the study of strains, displacements, pressures, light intensities, temperatures, d-c or a-c voltages or currents.

Write for time-saving help stating your problems. The Brush Development Company, Dept. A-6, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A. *Canadian Representatives:* A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario.

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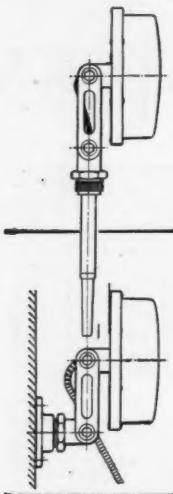
PALMER

mercury actuated Dial Thermometers

now in three types to suit any requirements

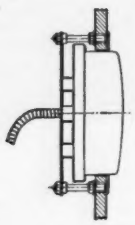


1 Rigid Stem Dial Thermometer

Rigid stem tapered bulb, interchangeable with standard industrial thermometer separable socket.

2 Wall Mounted Dial Thermometer

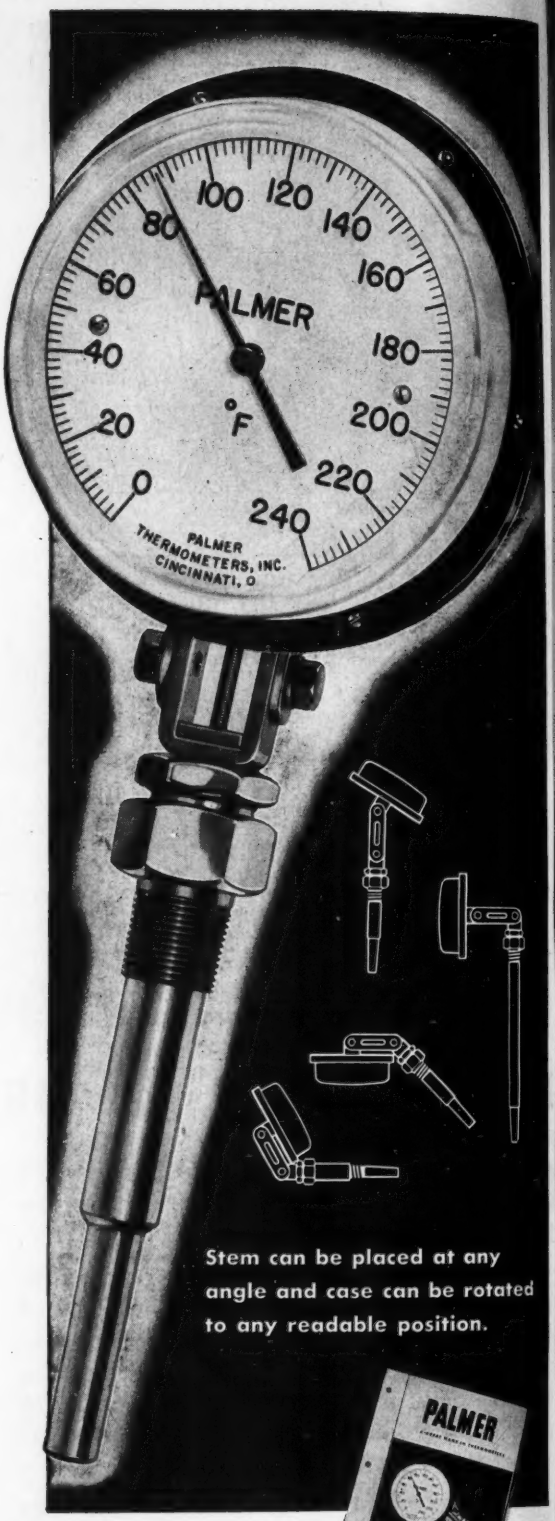
Wall mounted dial thermometer with flexible connecting armor. Case adjustable to easy reading position.



3 Flush Mounted Dial Thermometer

Flush mounted style for panel mounting with flexible connecting armor.

All three types have a full 4½" dial Face



Stem can be placed at any angle and case can be rotated to any readable position.

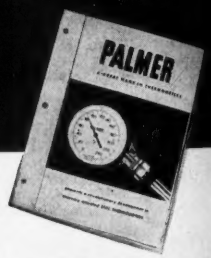
for accuracy: Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for angularity: Can be adjusted to most readable position at any angle desired.

for readability: Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

for interchangeability: Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

Visit our Booth No. 140-142 at the National Instrument Conference and Exhibit, Houston, Texas, September 10-14, 1951.



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For details on the New Palmer Dial Thermometer, please write for Palmer Bulletin 51-129.

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Versatility

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CREATES NEW APPROACHES FOR RESEARCH AND PROCESS DEVELOPMENT

The American D. C. Amplifier – a new, unique electro mechanical feedback amplifier – assures stable, accurate D. C. amplification so vital in engineering and process research.

The heart of this precision instrument is the power-actuated Microsen Balance, a unit extremely sensitive to low power input – insensitive to line voltage variations. It maintains continuous equilibrium between the forces created by the input current and those resulting from the output current. Consequently, the result is precision D.C. amplification.

The American D. C. Amplifier is highly versatile. Some fields of measurement in which it is applied are: electronics, electrical bridges, electrolysis, gas analysis, photometry, and thermometry. It has been used with Pirani gauges, photocells, and ionization gauges. Standard units include Voltage, Current, and Potentiometer Amplifiers, D. C. Converters and D. C. Transformers.

The American D. C. Amplifier is low in cost, easy to operate, compact, portable. Special designs can be engineered, if specific details are supplied. Mail the coupon for complete details. →

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☐ Please send me American D. C. Amplifier bulletin.
☐ Application specifications and/or specific queries attached.

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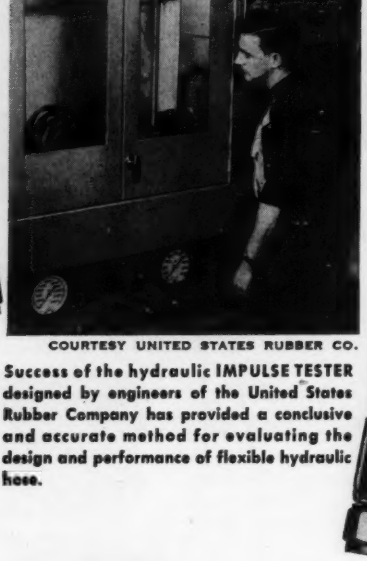
another Case History for

DU MONT OSCILLOGRAPHY



COURTESY UNITED STATES RUBBER CO.

Success of the hydraulic IMPULSE TESTER designed by engineers of the United States Rubber Company has provided a conclusive and accurate method for evaluating the design and performance of flexible hydraulic hose.

COURTESY UNITED STATES RUBBER CO.

With its slow, driven sweeps, and d-c amplification, the Du Mont Type 250-AH CATHODE-RAY OSCILLOGRAPH is an important key to the accuracy of this "fatigue test," and to the proper operation of the impulse-test equipment.

an approved hydraulic impulse test

● Engineers of the United States Rubber Company have designed and built a prime mover whose pressure output can be tailored to conform with strict impulse-test specifications — particularly those for hydraulic hose MIL-H5511 and MIL-H5512. Through their development, it is now possible to produce *test-proved* hose for the hydraulic systems operating landing gears and control surfaces in government aircraft. And their understanding of the inherent capabilities of the cathode-ray oscillograph and its application has contributed to the completeness and accuracy of this impulse-test technique.

Thirty five times a minute, for fifty continuous hours, test lengths of the hydraulic hose are subjected to controlled dynamic pressure pulses which rise to 150% of rated pressure. Air-aged, oil-aged, and unaged hose is impulse-tested under conditions of excessive tension and unusual compression and must withstand the stresses applied under these hydraulic shocks without exhibiting fatigue.

Simultaneously, each control-impulse cycle is applied to the cathode-ray oscillograph, where both static and dynamic levels of the pressure pulse are recorded. And, because the pressure pattern can be observed in complete detail on the cathode-ray oscillograph, slightest deformation of the hose is detected as a deviation from the specified pressure-pulse pattern.

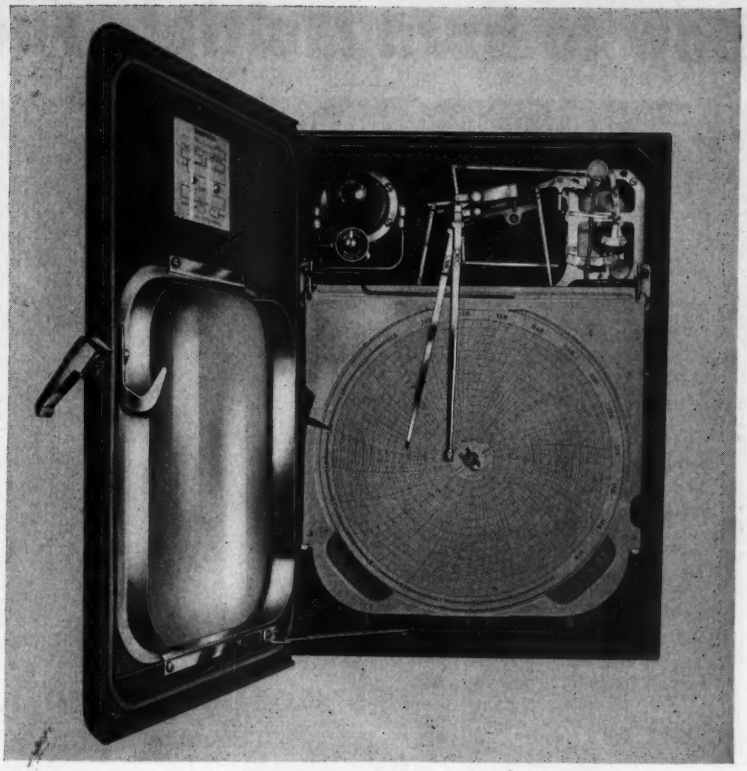
Also, faulty operation of the Impulse Tester can be detected on the cathode-ray oscillograph. And by proper interpretation of this pattern, troubles can be localized and corrected quickly.

The functions of the cathode-ray oscillograph in this hydraulic application are but typical of the diversity of fields in which it is finding more and more important uses.

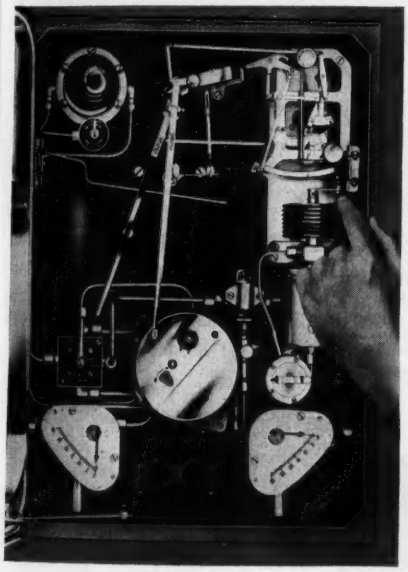
DUMONT *for Oscillography*

Allen B. Du Mont Laboratories, Inc., Instrument Division, 1000 Main Ave., Clifton, N.J.

Anybody Can Take Care of a BRISTOL SERIES 500 CONTROLLER



Plant operating men quickly become familiar with it . . . and like to use it



Only One Simple Adjustment

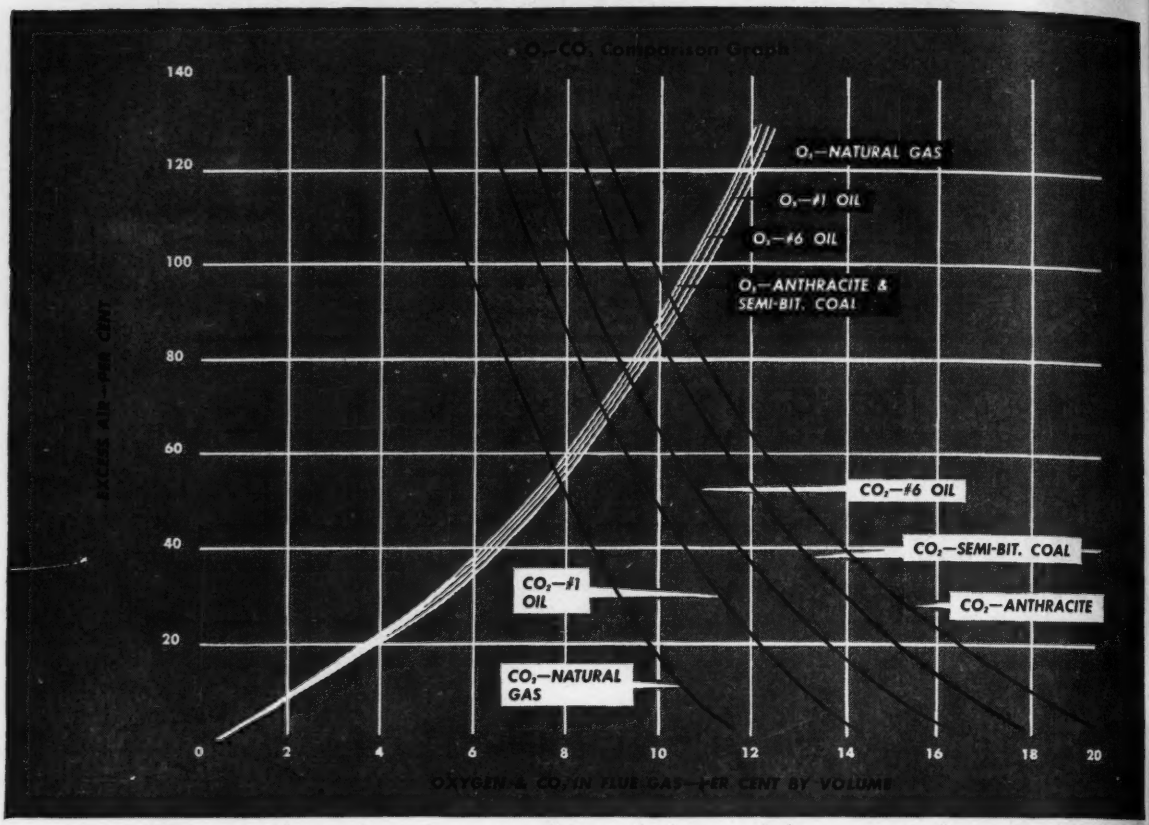
Write or call your local Bristol representative. And write for Bulletin A120. THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 20, Conn.

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

How to burn Multiple Fuels efficiently



Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

When switching from one fuel to another or burning more than one fuel at the same time, you can realize large savings with a continuous indication of Oxygen content in your flue gas—because Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

This fact is borne out by the graph showing the relationship of excess air to CO_2 and O_2 in the flue gas of five common fuels. While the O_2 curves nearly coincide (especially in the important 30% excess air range) the CO_2 curves diverge widely.

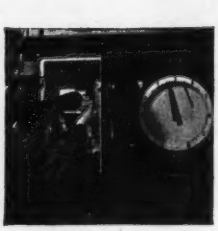
Large Savings Possible

This deviation was costing a medium sized refinery in Michigan $35-40 per day in boiler room fuel costs. Burning a combination of oil and gas they found that a combustion control system to handle their multiple fuel firing conditions would cost more than their small boilers.

They purchased a Hays Magno-Therm Oxygen Recorder, and immediately found that their boiler operation was so inefficient that the pen would not stay on the 0-10% chart. However, by operating with reference to the O_2 recorder they were able to reduce fuel costs enough *to pay for the instrument in 40 days.*

With the Hays Magno-Therm Oxygen Recorder you get:

Continuous, highly accurate indication and recording.
Complete compensation for temperature and pressure effects.
Freedom from chemicals or hazardous fuel burning in the analyzing process.
Swift, sure electronic operation.



If you are facing the problem of multiple fuel combustion, you will want a detailed copy of this O_2-CO$_2$ Comparison Graph as well as Hays Bulletin 50-829—describing the Magno-Therm Oxygen Recorder. Write for this free information.

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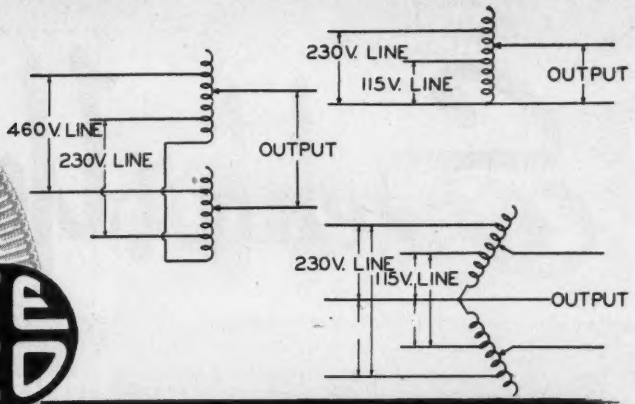
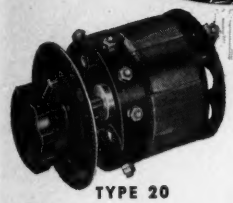


A TYPE FOR EACH APPLICATION



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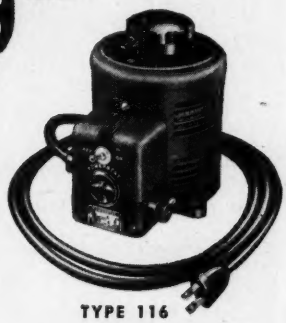

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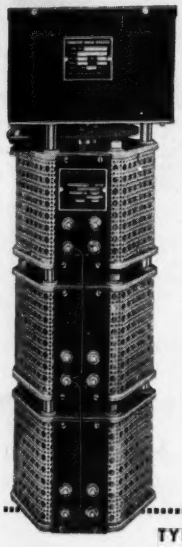

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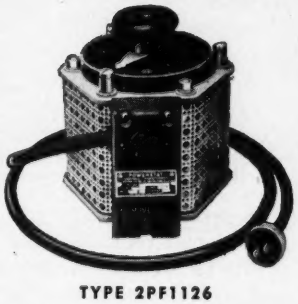

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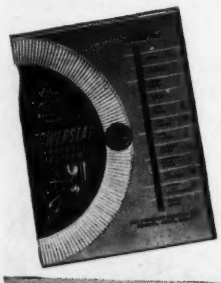

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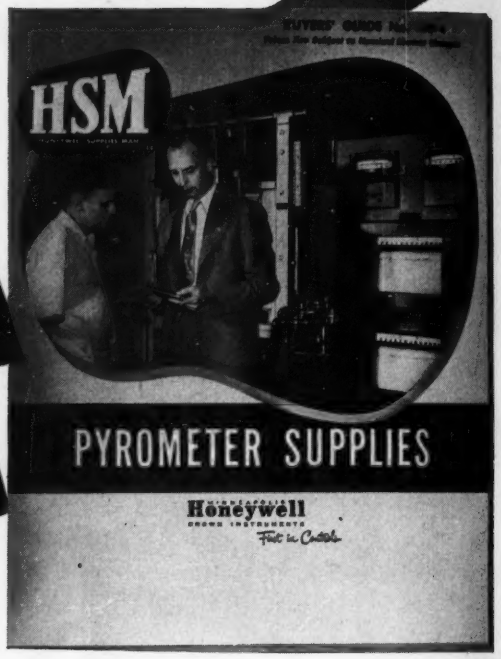

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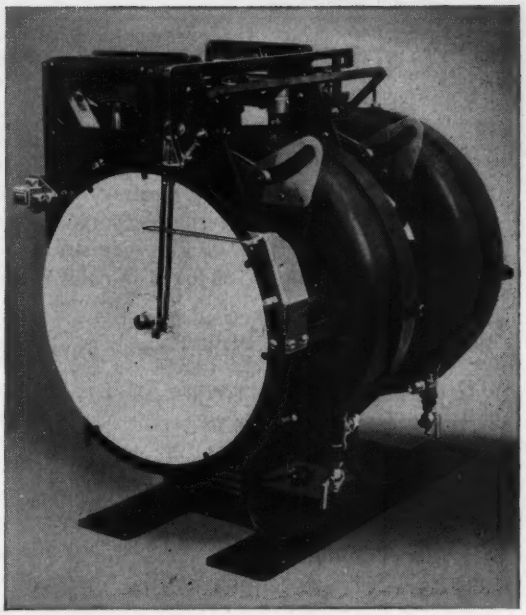

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In Hagan Ring Balance Meters the torque resulting from a given differential can be made high by using a ring with large cross-sectional area. Friction is low because of the knife-edge bearing on which the ring is mounted. The high torque-to-friction ratio thus obtained permits full scale operation with a differential as low as *one inch* of water.

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Few meters have *any* of these features; only Hagan Ring Balance has them all.

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nothing else can do what Microcarb does!

Microcarb is a control system for the carburizing process. It *continuously* measures something that nobody has ever measured before—the active carbon in a production furnace's atmosphere *while the furnace is at work in the heat-treat department.* And it automatically, continuously controls the surface carbon content of the steel on the basis of this measurement.

Microcarb is many things to many men, especially in defense work.

To top management, Microcarb means both higher product quality and lower unit cost! Also, it means that still another manufacturing operation comes under automatic control.

To production executives, Microcarb means closer following of manufacturing schedules, because carburizing speed and results are more predictable. More predictable, that is, even than with our own pre-Microcarb processing installations. And Microcarb helps heat-treaters apply their skill—helps them earn incentive pay.

To metallurgists, Microcarb means simply better carburizing. Perhaps you saw a recent magazine advertisement headed "Thank You, Leeds & Northrup!" in which Indiana Gear Works credits Microcarb as a "big help to the gear industry" and says

> "now, for the first time, we are able to control case carbon content on carburized parts"
>
> ". . . we can produce carburized surfaces with absolute uniform control and obtain absolute maximum hardness and maximum ductility"
>
> "no more retained austenite on wearing surfaces of high nickel steels"
>
> ". . . no more carbide networks in the hypereutectoid zone"

Such results trace back to the fact that with Microcarb the carbon you "set" is the carbon you get. Just as you set a temperature controller at 1700 F, if that is the carburizing temperature you want, so you set the Microcarb Controller at 90 if you want to carburize to ninety carbon. By making the proper setting, you can either protect the surface or add carbon. Instead of controlling the amount of carbon material supplied to the process, you actually control the amount that does the work. Can you imagine controlling the temperature of a furnace by just measuring the amount of fuel it gets, without a pyrometer to tell the temperature directly? Well, that's the kind of carbon control you have always had—until Microcarb. Microcarb measures and controls carbon directly, just as a pyrometer measures and controls temperature directly.

The "reason why" for Microcarb is its carbon-detecting element. This instrument, called a Carbohm, is an engineering rarity—a truly new device for sensing a change in its surroundings. Basically, it's a wire, made of an alloy which will either absorb carbon from the furnace atmosphere, or lose it to the atmosphere, until it and the atmosphere are in equilibrium, carbon-wise. With every change in the wire's carbon content, there's a change in its electrical resistance. This resistance is measured and translated into carbon percentage by the Microcarb recorder and controller.

Only Homocarb Furnace equipments of our new Series H can be used with Microcarb Control, because engineering to meet the needs of atmosphere regulation is a necessity. Specific features are a soundly designed electric furnace with solid-bottom retort, improved fan housing and work support, and aerodynamically designed discharge jets; and Micromax temperature control of the duration-adjusting type specially designed for this service.

Let us send you further facts about this new Microcarb development. Ask our nearest office, or 4955 Stenton Ave., Phila. 44, Pa., for Catalog T-623.

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

"Selling" You to Top Executives

On page 1047 there appears a facsimile reproduction of the first of twelve advertisements inserted by The Instruments Publishing Company in *Dun's Review*. It ought to be a good "facsimile" for it is printed from the same plate! We intend to reproduce most (if not all) of those *Dun's Review* ads in *Instruments* so that you may see how twelve different advertising agencies "sell" instruments—and, implicitly, Instrument Men—to the financial executives who often decide what percent of the outlay for each new plant goes for instrumentation.

Two More European Reports Next Month

In this issue, Publisher Rimbach reports on the trips he made to Europe this year. His coverage is broad. In October there will appear two specialized reports: (1) one describing German instrument developments; (2) a report on last July's Conference on Automatic Control sponsored by an English government department.

Compressed Air for the Instrument Exhibit

Seven hundred cubic feet per minute!

This is one statistic about the 1951 Instrument Show that we have heard from various well-informed sources. It certainly is impressive!

But it must not be misinterpreted. For example it does not mean that the latest models of pneumatic instruments consume more compressed air than the older models. On the contrary! Some of the newest instruments have jewel-like air valves which impose practically no drag on the measuring systems and consume cubic INCHES rather than cubic feet per hour.

Why then the need of such a large supply of compressed air? Is it because there will be tens of thousands of pneumatic instruments all operating at the same time? Not at all! At most, about a hundred will be "on" at any moment.

The answer can be summarized in three words: stages of amplification.

A pneumatic control system starts with a measuring system commanding a tiny prime relay. This prime relay continuously commands a secondary pilot, which actuates a power device either directly or by more intermediate relays. The final stage may be of integral-horsepower rating.

In fact, there's no reason why the final stage of ONE small pneumatic instrument, in any of a dozen booths, couldn't be the entire air-compressor installation!

M & C Handbook to U.S. and Canada Only

By this time, distribution of the Handbook of Measurement and Control has been completed. If you subscribed in accordance with the special offer, you should have received your copy. The offer applied only to the U.S. and Canada. Consequently, no books are being sent abroad by The Instruments Publishing Company.

A New Service

As most of our readers know, the *Manufacturers' Literature Department* is a treasure chest of useful and important information. To make this information of more value to you, and to save your time, we have classified this department so that you can quickly find information on temperature, pressure, flow, optical instruments, chemical laboratory instruments, electrical and electronic instruments, electrical and electronic components, valves, shop equipment, etc. This extensive department is a rich source of information. Develop the habit of using it.

Duplication of Effort Still Rates "Crime" Tag

Nearly twenty years ago we paid a heartfelt compliment to Dr. Ellice MacDonald for making part of his annual report* into an excellent "editorial" against duplication of effort—which duplication he called "That Crime Against Research." We thanked Dr. MacDonald for a sermon which was—and is—not only applicable to the field of solving important problems in research, but to the field served by *Instruments*: the field of solving daily problems in measurement, inspection, metering, gaging, manual control, automatic control, etc.

All too often, when the exact combination of elements is not immediately available, someone may say, "Oh, no use 'phoning the other suppliers. Let's build our own!" All too often, it's when such a suggestion is made (with good intentions, of course!) that there begins a waste of time and effort—a needless waste, a shocking waste, yes, a criminal waste.

The foregoing is familiar to old subscribers. (No apology for reprinting it: once a year wouldn't be too often.) The reason, this time, is new and astonishing: A reader proudly submitted an article on how to make "An Economical" portable thermocouple pyrometer—but his costs omitted company time and we concluded that the time it would take to make the computations, to order the parts, to inspect them, to assemble them, etc., would cost a company or institution much more than the price of a ready-to-use outfit such as has been on the market for a quarter-century.—MFB

*As Director of the Biological Research Foundation of the Franklin Institute.

Measurement *and* Control *in the* Utilization *of* Mixed Fuels *and* Oxygen *in* Open-hearth Furnaces

By MARTIN J. CONWAY, Consulting Engineer, Gap, Penna.,
and EDWARD H. CAUGER, Chief Combustion Engineer, Steubenville Works, Wheeling Steel Corp.

Instrumentation and combustion techniques have made it possible for open-hearths designed for 60-ton heats to produce heats of 170 tons with reduced fuel consumption per ton and increased checker life. Fuel temperature, viscosity, and flow are controlled, as are furnace pressure, oxygen flow and air flow.

INSTALLATION of measurement and automatic-control instruments on open-hearth furnaces provides the operator with means to duplicate functional operation and to obtain improved fuel consumption and increased furnace production.

Before describing the measurement and control equipment installed on the open-hearth furnaces at the Steubenville Works of the Wheeling Steel Corporation, it should be mentioned that the types of fuel used are coke-plant tar, bunker "C" fuel oil, and coke-oven gas. Tar and oil are not used simultaneously on any furnace, but a furnace can be switched from one liquid fuel to another as conditions demand. Plans are now being formulated to use a combination of these two fuels. Present practice is to use the coke-oven gas chiefly during the melt-down period, while tar is the preferred liquid fuel because its high luminosity makes it radiate heat to the molten-steel bath through the slag blanket better than oil. As coke-oven gas is nonluminous, it must release its heat by conduction and convection.

In addition to the coke-oven gas and liquid fuels, oxygen of 95 percent purity is used for both combustion and decarbonization.

The open-hearth furnaces were designed and built to produce 60-ton heats. They had ample regeneration chamber capacity to preheat sufficient air for burning the fuel to melt this tonnage. However, as the same furnaces now produce heats of about 170 tons, sufficient preheated air is not available to melt this tonnage in reasonable time and with comparable fuel consumption. Therefore, combustion oxygen is introduced when burning more than 375 gallons of fuel oil equivalent per hour.

Oxygen is introduced into the molten metal bath during the refining period of the heat—both for carbon-reduction acceleration and for temperature requirements. The oxygen is introduced by inserting a ¾-inch lance into the bath through the wicket hole of the furnace door. A standard globe valve is used to control the volume of oxygen feeding the lance from a 110-psig. oxygen line. A pressure gage indicates the pressure on the lance line. As a protection to the operator of the lance, a quick-closing safety valve is installed on the outlet side of the globe valve, which is held open by the helper regulating the oxygen to the lance.

A recorder which measures all the oxygen used for decarbonization in the eleven furnaces is installed on a master panel in the Gas Dispatcher's office. This master panel (Fig. 1) contains, in addition to the decarbonization-oxygen meter, recorders and indicators for (1) total combustion oxygen, (2) total coke-oven gas available for distribution from the coke plant to the steel plant and other services, and (3) coke-oven gas consumption in the boiler plants, strip mill, individual open-hearth furnaces, and the Corporation's manufacturing plants located some 15 miles down-river from the Steubenville Works. The recorders are telemetered from integrating recorders.

Presented at the Conference "Instrumentation for the Iron and Steel Industry," sponsored by the Carnegie Institute of Technology and the Pittsburgh Section, Instrument Society of America, March 28 and 29, 1951, Hotel Roosevelt, Pittsburgh, Penna.

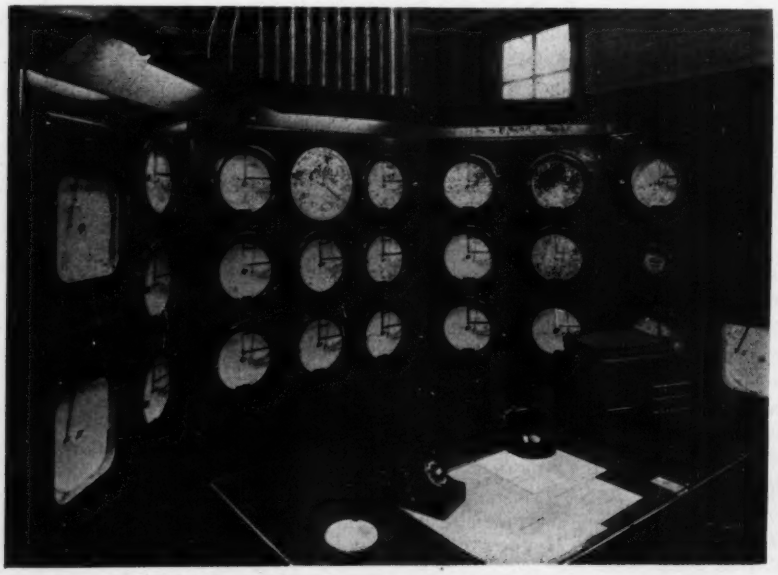


Fig. 1. Gas Dispatcher's panel.

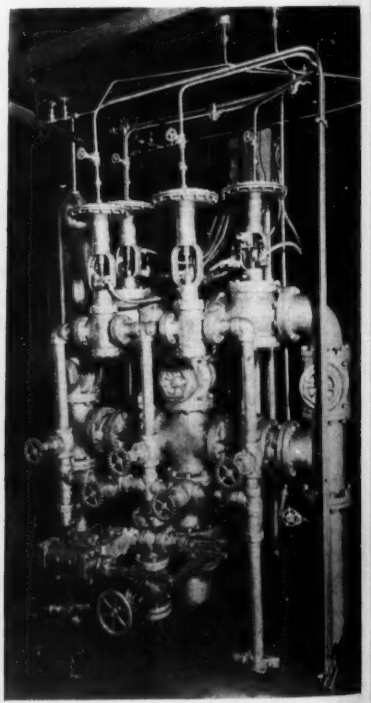


Fig. 2. Coke-oven-gas and oxygen manifolds.

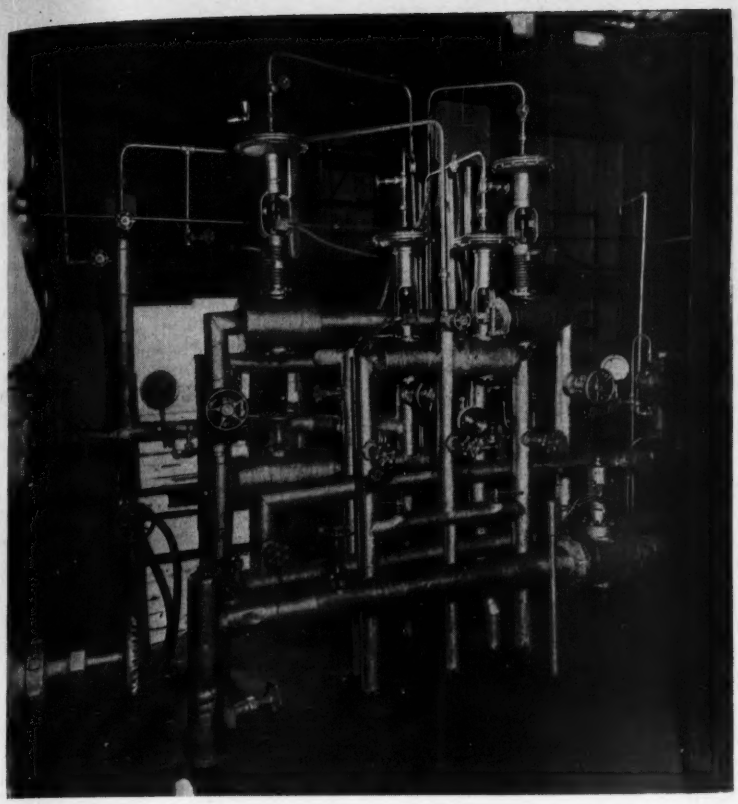


Fig. 3. Oil and steam manifolds.

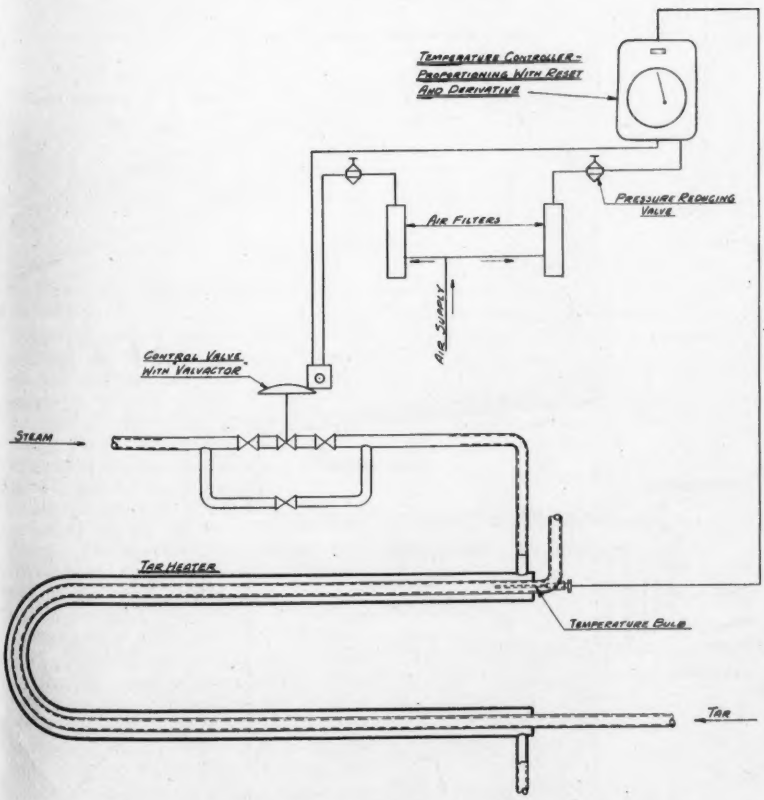


Fig. 4. Tar-temperature control system.

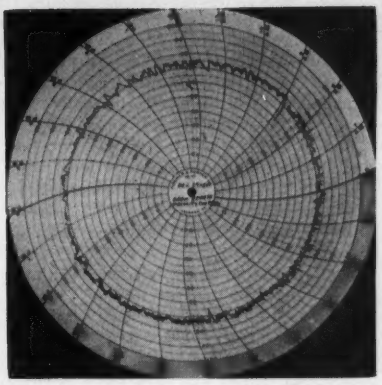


Fig. 5. Oil-viscosity control chart.

The oxygen is produced by an oxygen-generating plant adjacent to the open-hearth shop. It is delivered to the furnaces through a 110-psig. line for decarbonization and refining, and through a 45-psig. line for combustion. Fig. 2 shows coke-oven gas and oxygen manifolds. Fig. 3 shows oil and steam manifolds.

Tar temperature is maintained by a controller which regulates the steam to a tubular heat exchanger. Fig. 4 is a diagram of the tar-temperature control. The "Valvactor" enables the instrument to accurately position the control valve with small changes in air pressure from the instrument, thereby overcoming valve friction. The control valve is a double-seated V-port valve with top- and bottom-guided construction.

Fuel-Oil Temperature and Viscosity Control

Oil temperature can be controlled in a manner similar to the tar temperature. A viscosity control is used also. Oil flow, temperature, and viscosity are recorded on charts. The viscosity chart (Fig. 5) records percentage of minimum viscosity, which is approximately 175 USS for present practice. The swing is due to the lag caused by the distance between the viscosity controller and the valve which controls the steam input to the heater. In addition, the steam valve is somewhat oversized, which tends to accentuate the swings.

The viscosity-control installation is shown in Fig. 6. The continuous viscosimeter is a simple adaptation of the well-known variable-area flow-rate meter in which the flow rate is measured by causing floats to move vertically upward in a tapered tube as the flow rate increases, and to drop as the flow rate decreases. The floats can be either viscosity-sensitive or viscosity-immune. Two floats are installed in the tapered tube, one above the other. The lower float is viscosity-immune and responds only to flow. The upper float is viscosity-sensitive and responds to both flow and viscosity change. Thus the gap between the two floats is related to viscosity.

The viscosimeter is installed in a by-

pass of the main oil-delivery line. Enough regular flow to lift the lower float to a reference line is made to flow through the viscosimeter. By use of impedance coils at the top and bottom of the unit, the rate of flow and the viscosity are transmitted to the recorder controller. The controller transmits air pressure to a diaphragm valve in the steam line to the oil heater, thereby making the required adjustments.

The main steam-supply line for liquid-fuel atomization carries 250-psig. superheated steam at a temperature of 600 F. The atomizers used have been conventional T-type atomizers which are fabricated in the Corporation's Service Shops. However, after several months of experimentation it has been decided to standardize on a commercial type of atomizer both for uniformity and for improved atomization. Fig. 7 shows the standard open-hearth furnace burner used in these operations. The burner is independent of the attached liquid-fuel atomizers. Note that the oxygen nozzle is in a low position. This is because the high temperature developed by the accelerated combustion of the atomized fuel due to the introduction of combustion oxygen should be as close to the hearth and as far from the roof as possible. Several commercial-type burners have been used experimentally with varying degrees of success. As their design does not allow for adjustment, it has been the practice to fabricate this part of the equipment in the Corporation's Service Departments. This practice probably will continue while the best liquid-fuel atomizing equipment to suit the furnace operation is sought.

Furnace-Pressure Control

Fig. 8 illustrates the arrangement for furnace-pressure control.

The furnace pressure is measured at the crown of the furnace roof by pipe connections both inside and outside the furnace. The differential is transmitted to the furnace-pressure regulator mounted on the panel board. The value of the furnace pressure to be maintained is set on dial A, which is mounted on the front of the panel. The regulator controls the stack-damper position by operating a double-acting cylinder, which is connected to the damper and counter-weighted by means of sheaves and cables. It is important that the damper be as nearly counterbalanced as possible, thereby allowing the double-acting cylinder to move the damper at the same speed in both directions. Only one set of impulse lines serves both the roof-pressure recorder and the regulator.

Fuel Control and Summarization

Fig. 9 is a schematic diagram of the fuel control and summarization. The combustion controls are arranged so that the heat input, or total Btu. supplied to the furnace, can be set by the operator. This is accomplished by adjusting handwheel B, which acts through a mechanical computer or totalizer, which in turn controls the proportional amounts of liquid or gaseous fuel. This operation is accomplished by converting the stroke of shaft C of the summarizer into a spring-loading force by means of an adjustable cam. This causes the regulator to provide a specific volume of liquid fuel.

By setting the amount of gas desired on handwheel D, the stroke of shaft E of the summarizer is transformed into a spring-loading pressure by means of an adjustable cam, thereby operating the regulator to provide a comparable volume of gas in a manner similar to the way that the liquid fuel is supplied.

Oil flow is indicated and recorded by means of a conventional area meter. However, fuel oil for the combustion-control system is measured by means of a differential-type meter with a pneumatic signal-transmitting system as follows: Oil entering the differential-meter body acts on a piston to maintain a constant differential across valve F. The valve is, in effect, a variable orifice across which a constant differential is maintained so that the opening of the orifice is an indication of flow.

Air pilot-valve G is linked to the oil flow-control valve so that it is positioned similarly. A pilot air flow is admitted to valve G. A constant differential of air is maintained across this

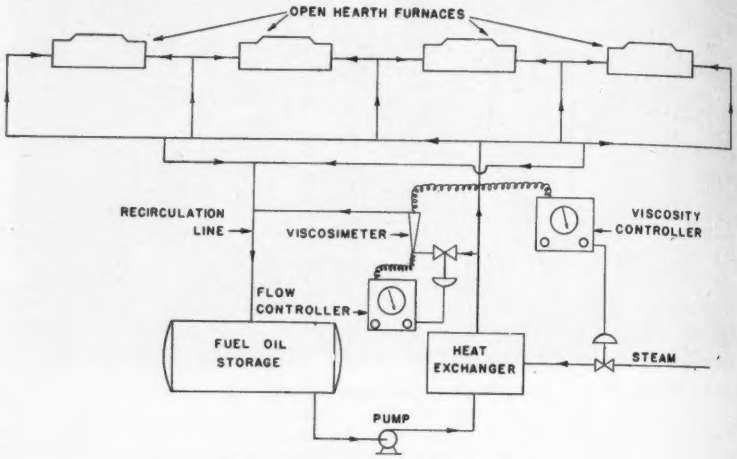


Fig. 6. Oil-viscosity control installation.

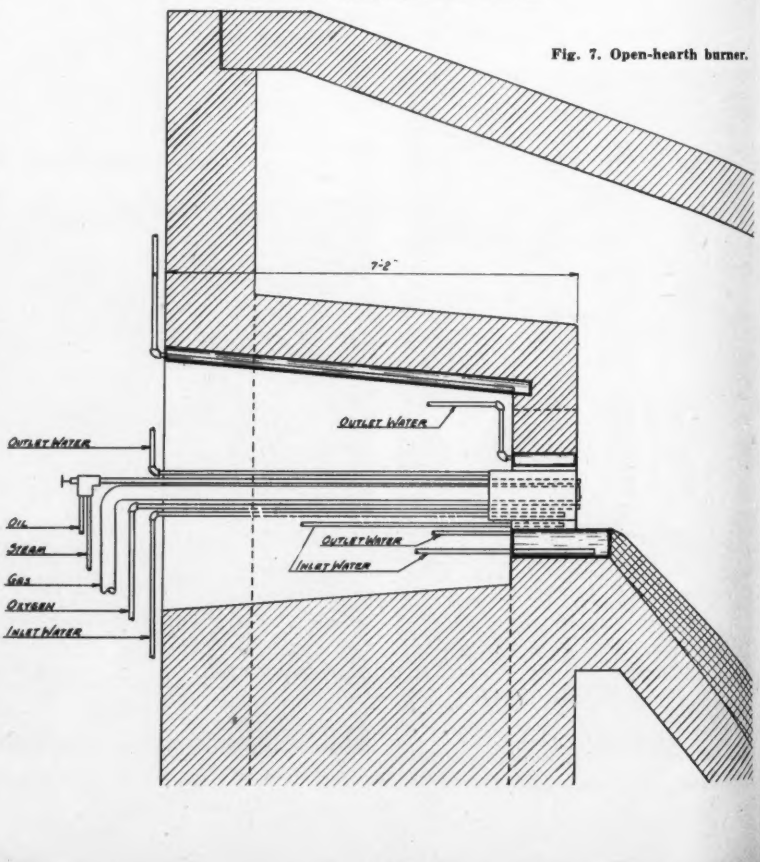


Fig. 7. Open-hearth burner.

valve by means of a pressure regulator so that its position, as well as the volume of air flowing through it, becomes a measure of oil flow. The pilot air flow is measured by an orifice. The upstream pressure connection, which varies approximately as the square of the air flow, is transmitted to the oil-flow regulator to balance the spring-loading pressure developed by the cam.

Coke-oven gas flow is measured by a conventional orifice plate. The differential developed serves both an electric-meter body, which transmits the flow impulse to the recorder and totalizer, and the gas-flow regulator. This differential balances the spring-loading force developed by the stroke of shaft E of the summarizer. Coke-oven gas pressure is indicated by a conventional pressure gage.

Oxygen and Air Summarization

Fig. 10 is a schematic diagram of the oxygen and air control and summarization. The output of the fuel computer (or summarizer) is indicated by the stroke of shaft H of the summarizer. This shaft, which is connected to the total-input shaft of the oxygen and air computer, signals the adjustments for air and oxygen.

Shaft I of the summarizer exactly matches the stroke of shaft H when shaft J is stationary. Shaft I is connected to a cam which, in the same manner as described previously, develops the spring-loading force to provide for a specific volume of air to burn the amount of fuel determined by the movement of shaft H. It does this by adjusting an air valve in the fan discharge. Air volume is measured by a conventional orifice plate; the differential developed is transmitted to a remote recorder and balances the spring-loading force developed by the cam.

The operator may replace a certain amount of atmospheric air with combustion oxygen delivered to the burner. He makes this adjustment by setting handwheel K to the desired oxygen volume. This handwheel, through the totalizer, deducts the air equivalent of the oxygen from the total delivered to the furnace. Oxygen volume is transformed by the stroke of shaft J of the totalizer, which calls for the required volume of oxygen in the manner described — that is, by developing the spring-loading force through a cam which in turn is balanced by the orifice measurement.

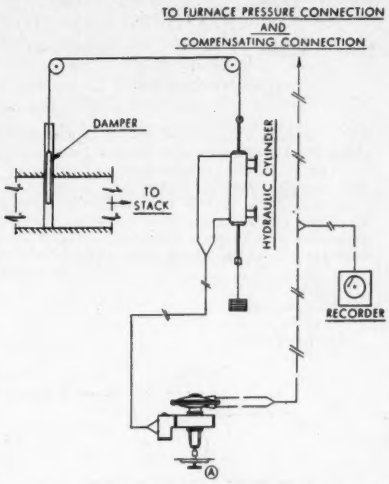


Fig. 8. Furnace-pressure control system.

The differential developed by the orifice serves both the regulator and the electric-meter body, which transmits electrical signals to the remote recorder. The regulator adjusts the oxygen flow through a plug-type valve equipped with special packing. The system is designed in such a manner that oxygen cannot come in contact with the oil serving as a hydraulic medium for the regulator.

Fuel-air ratio is adjusted by simultaneously setting the ratio sliders using handwheel L on the panel board.

Atomizing Steam

The original system controlled the atomizing steam through a diaphragm valve actuated by a proportional-control regulator, which air loaded the steam-flow valve. However, this method has been replaced by a pneumatic system with manual loading of the diaphragm valve by a drift-proof regulator from the front of the panel board. Steam flow is measured by an orifice and electric-meter body for a remote totalizing recorder.

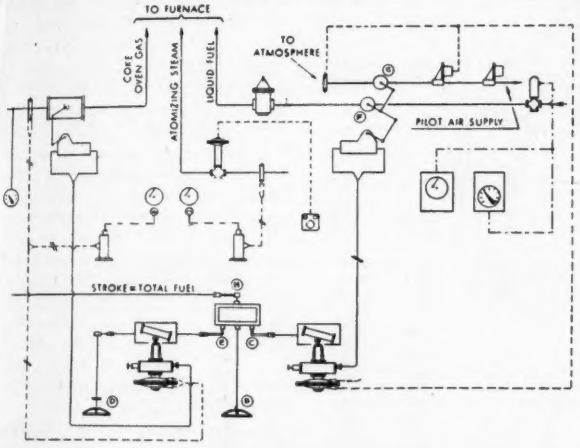


Fig. 9. Fuel controller and summarizer.

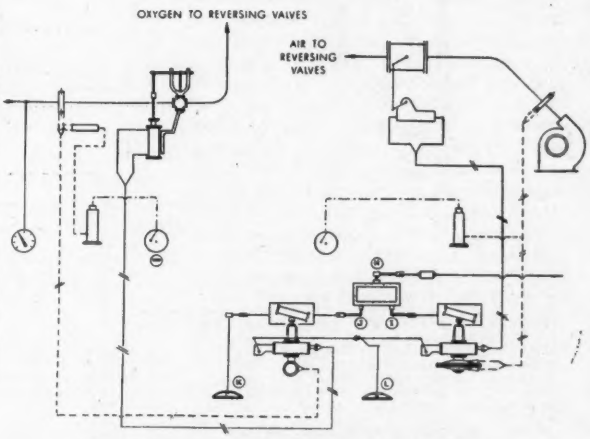


Fig. 10. Oxygen and air controller and summarizer.

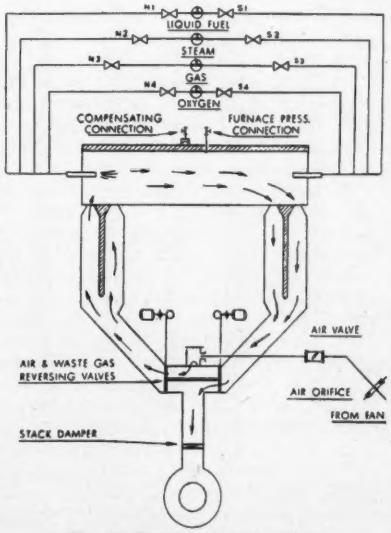


Fig. 11. Furnace-reversal system.

Automatic Reversal

The furnace may be reversed according to either maximum checker temperature or a preset time interval.

The reversal valves for liquid fuel, steam, gas, and oxygen are of the diaphragm type and are operated through a solenoid three-way valve, which admits air to the diaphragm motor.

Waste gas and combustion air are reversed by a double-deck-type damper operated by an electric motor.

The solenoid valves and damper-motor starter are energized by the timer or checker-temperature difference controller, which act through interlocks and relays to accomplish the sequence of reversal as follows (Fig. 11):

(1) Close north oil-reversing valve N_1.

(2) Close north gas-reversing valve N_3.

(3) Close north oxygen-reversing valve N_4.

(4) Close north steam-reversing valve N_2 (delayed action).

(5) Open south steam-reversing valve S_2.

(6) Open south oxygen-reversing valve S_4.

(7) Fuel, air, oxygen-control valves, and stack damper are locked in position.

(8) Waste gas and air valves are reversed.

(9) Time interval allowed to purge checkers before fuel is turned on.

(10) Open south gas-reversing valve S_3.

(11) Open south oil-reversing valve S_1.

(12) Restore control of fuel, air, oxygen, and stack damper to regulators.

Table I shows the furnace controls, recorders, and indicators.

Fig. 12 is the log of a random heat.

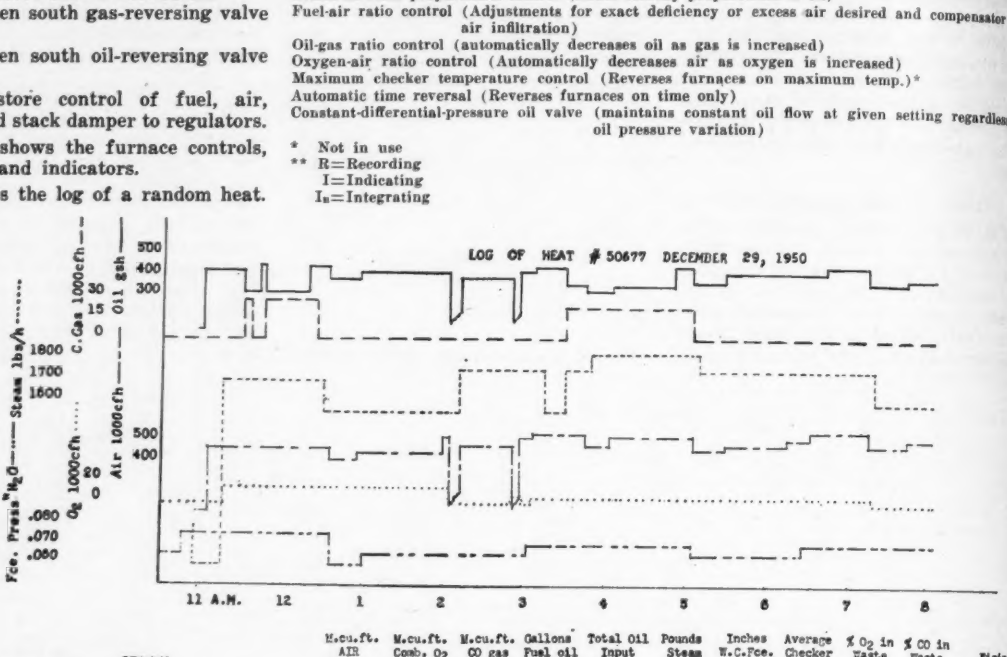
TABLE I—INSTRUMENTS ON OPEN-HEARTH FURNACES, STEUBENVILLE WORKS, WHEELING STEEL

**	O_2	Oil or Tar	CO	Comb. Air.	Atomizing Steam	Draft
Flowmeter	R & I_n Comb. only	R & I_n & I	R & I_n	R	R & I_n	
Pressure gages	I Comb. & Ref.	I	I		I	R-(Fce.P.)
Temp. measure.	R @ O_2 Plant Comb. & Ref.	R(oil & tar)		R & I (Regenerator-Temp.)	I	—

CONTROLS

Steam-oil ratio proportional control (steam directly proportional to oil)*
Fuel-air ratio control (Adjustments for exact deficiency or excess air desired and compensator for air infiltration)
Oil-gas ratio control (automatically decreases oil as gas is increased)
Oxygen-air ratio control (Automatically decreases air as oxygen is increased)
Maximum checker temperature control (Reverses furnaces on maximum temp.)*
Automatic time reversal (Reverses furnaces on time only)
Constant-differential-pressure oil valve (maintains constant oil flow at given setting regardless of oil pressure variation)

* Not in use
** R=Recording
I=Indicating
I_n=Integrating



TIME	REMARKS	M.cu.ft. AIR per hr.	M.cu.ft. Comb. O_2 per hr.	M.cu.ft. CO gas per hr.	Gallons Fuel oil per hr.	Total Oil Input per hr.	Pounds Steam per hr.	Inches W.C.Fce. Pressure	Average Checker Temp. °F.	% O_2 in Waste Gas	% CO in Waste Gas	Firing Direction
10:22 A.M.	Fuel off after heat 50676	0	0	0	0	0	1000	0.065	2000	-	-	-
10:48 A.M.	Set fuel air ratio ? 105%-raised fce pressure	0	0	0	0	0	800	0.075	1900	-	-	-
10:51 A.M.	Finish fettling-start chg.-oil cold in manifold, not following regulator	168	0	0	150	190	800	0.075	1880	-	-	-
11:13 A.M.	Clean Burners 2nd drag scrap	480	15	0	450	450	1700	0.075	1865	-	-	-
11:33 A.M.	Coke oven gas on	480/	15	28	320	460	1650	0.075	1840	-	-	-
11:43 A.M.	Gas off- Reclean Burner	480/	15	0	460	460	1750	0.075	1840	-	-	-
11:49 A.M.	Gas back on- Fin. 2nd drag scrap	480/	15	28	320	460	1650	0.075	1800	-	-	-
12:20 P.M.		480/	15	28	320	460	1700	0.075	1820	6.8	0	N to S
12:30 P.M.	Gas off	480/	15	0	450	460	1700	0.075	1840	6.8-5.8	0-0	NtoS and StoN
12:40 P.M.	St. 3rd drag-cut fuel -fce. too hot	414	15	0	390	400	1550	0.065	1860	-	-	-
1:00 P.M.	Fin. 3rd drag-raise fuel	450	15	0	420	430	1550	0.065	1800	-	-	-
1:16 P.M.	St. last drag scrap	450	15	0	420	430	1650	0.065	1840	-	-	-
1:34 P.M.	Finish chg.	450	15	0	420	430	1550	0.065	1820	-	-	-
1:50 P.M.	Doors Banked	450	15	0	420	430	1550	0.065	1830	1.8-1.8	0-0	N to S S to N
2:03 P.M.	Raised fuel air ratio to 110-start hot metal	480	15	0	420	430	1550	0.065	1830	-	-	-
2:05 P.M.	Oxygen off	525	0	0	420	430	1600	0.065	1830	-	-	-
2:10 P.M.	Fuel off-Fce too hot-St. flushing	0	0	0	0	0	1750	0.065	1840	-	-	-
2:15 P.M.	Fuel back on-fin. first ladle	498	0	0	400	400	1650	0.065	1900	-	-	-
2:40 P.M.	Start 2nd ladle metal	498	0	0	400	400	1700	0.065	1900	-	-	-
2:44 P.M.	Comb. Oxygen on	480	6.5	0	400	400	1700	0.065	1900	-	-	-
2:49 P.M.	Finish metal	480	6.5	0	400	400	1700	0.065	1900	-	-	-
2:53 P.M.	Wild flush, Fce. broke out, loosing metal	0	0	0	0	0	1750	0.065	1950	-	-	-
2:58 P.M.	Lost 15,000 to 20,000# metal- stopped flush	516	0	0	415	415	1700	0.065	1900	-	-	-
3:02 P.M.	Put on oxygen, raised oil and fce. pressure	516	7.0	0	430	430	1650	0.070	1900	-	-	-
3:13 P.M.	Raised oil input	540	7.0	0	450	450	1750	0.070	1920	1.2	0	N to S
3:20 P.M.	Change rev from 10 min & 10 min. to 10 min off North & 11 min. off S.	540	7.0	0	450	450	1550	0.070	1920	2.0	0	S to N
3:35 P.M.	Coke oven gas on	540	7.0	20.5	365	450	1750	0.070	1930	0.0	1.0	N to S
3:48 P.M.	Cut fuel	492	7.0	20.5	325	410	1840	0.070	2000	-	-	-
4:10 P.M.	Raised fuel	522	7.0	20.5	355	440	1850	0.070	2040	-	-	-
4:53 P.M.	Shut off gas	522	7.0	0	430	440	1800	0.070	2050	0.4	0.6	N to S
5:05 P.M.	Cut fce pressure	522	7.0	0	430	430	1800	0.065	2060	-	-	-
5:10 P.M.	Reduced fuel	474	7.0	0	390	395	1710	0.065	2060	1.0	0	N to S
5:15 P.M.		474	7.0	0	390	395	1710	0.065	2050	0.4	0.2	S to N
5:35 P.M.	Raised fuel	498	7.0	0	415	420	1750	0.065	2060	1.3	0	S to N
5:45 P.M.		490	7.0	0	420	420	1660	0.065	2040	0.4	0.6	N to S
6:25 P.M.	Make up backwall & end banks-raised fuel & Fce press	516	7.0	0	430	440	1750	0.070	2050	-	-	-
6:30 P.M.		516	7.0	0	430	440	1750	0.070	2050	2.2	0	S to N
6:35 P.M.		516	7.0	0	430	440	1750	0.070	2050	1.6	0	N to S
6:40 P.M.	Raised fuel-making up front banks	552	7.0	0	460	460	1725	0.070	2060	-	-	-
7:19 P.M.	Comb. oxygen off-reduce fce. press.-reduced fuel 1st oxygen lance	492	0.0	0	380	390	1550	0.065	2060	-	-	-
7:27 P.M.	Shut off fuel-box of ore-raise fce. press.	0	0.0	0	0	0	1660	0.070	2070	-	-	-
7:28 P.M.	Fuel on	492	0.0	0	385	390	1660	0.070	2070	-	-	-
7:51 P.M.	Raised fuel acct hard tap	516	0	0	405	410	1550	0.070	2000	-	-	-
8:08 P.M.	Heat tapped	516	0.0	0	405	410	1550	0.070	2000	-	-	-
8:11 P.M.	Fuel off	0	0	0	0	0	800	0.070	2000	-	-	-

Total Coke oven gas	44,000 cu. ft.	Total Combustion Oxygen	66,000 cu. ft.	lbs. steam per ton	85.3	Net BTU/TON-Coke oven gas	128,460
Total Fuel Oil	3,470 Gals.	Total Refining Oxygen	10,540 cu. ft.	lbs. steam/gal. fuel oil	4.6	Net BTU/TON-Fuel oil	2,992,993
Total Steam	16,100 lbs.	Tons Steel tapped	169	Cu.ft. Comb. oxygen/ton	390.5	TOTAL BTU/TON	3,121,453
				Cu.ft. Refining oxygen/ton	62.4		
				Total Oxygen per ton	452.9		

Fig. 12. Log of heat No. 50677.

It shows the flows and pressures as they occurred, the advantages of measurement and control, and also the advantages of combustion oxygen, refining oxygen, and high hot-metal heats.

Above the tabulation in Fig. 12 is a graphic representation of fuel, steam, oxygen, and air flows, together with furnace pressure.

Note that as coke-oven gas was put on the furnace, the fuel oil was automatically reduced, whereas the Btu. input remained constant.

The reduction of furnace air input corresponding to the combustion oxygen addition is not seen so readily because simultaneously with the addition of combustion oxygen, the fuel input increased and the fuel-air ratio control increased the air input. However, even after the increase of fuel input, the furnace air did not exceed the quantity prior to the fuel increase because the air-oxygen ratio control maintained the air flow in accordance with the amount of combustion oxygen being used.

The log shows also that the oxygen content of the waste gases was kept in the desired range of 1.5 to 2.5 percent, except during the period when the heat was working violently and gases escaped from the furnace without being completely burned.

The steam input to the furnace was quite high. The steam-oil proportional control is not in use because steam must be varied to control flame characteristics suitable for the period of the heat, and the control cannot follow these conditions because the steam varies proportionately with the oil in this type of control. A ratio controller whereby an excess or deficiency of steam could be set, as in the fuel-air ratio control, would be desirable. However, the air-operated steam valve is now set remotely at the panel by means of the drift-proof regulator.

The furnace-pressure chart shows that the automatic furnace-pressure controller held the furnace pressure to the desired regulation throughout the heat.

After tapping the previous heat, the checkers became unbalanced while fettling and charging the subsequent heat. This condition was remedied readily by setting the timers to allow the furnace to work from the hot end longer than the cold end until both ends were brought into balance. As the checkers gained temperature, the furnace was reversed oftener. This was accomplished by resetting the timers for shorter reversals.

As indicated previously, the automatic control system has means of reversal if the checkers become too hot and endanger the brick work. This is not used because the impulse is derived from radiation units sighted at the top of the checker brick, and erroneous temperatures can be registered due to wisps of flame or burning dust sometimes carried over with the waste gases.

The final installation of the open-hearth furnace controls was made a little over a year ago. The Fuel Department personnel had to be trained in the functional use of the controls and their relationship to furnace operation in order to obtain the full benefit the controls were intended to produce —namely, increased production per furnace hour, lower fuel consumption per ton, and increased refractory life. Training of the furnace operators on the use of the controls and instrumentation proceeded concurrently with the training of the Fuel Department personnel. This training is still in progress and there is still room for improvement as an analysis of the log on heat No. 50677 (Fig. 12) reveals. Changes and experiments are being made constantly.

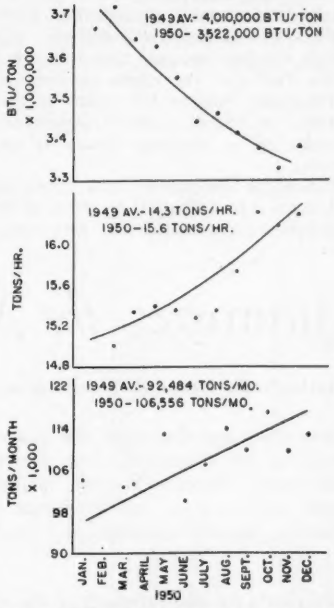


Fig. 13. Curves of Btu. per ton, tons production per furnace hour, and total production per month for Open-hearth Department, Steubenville North Works, Wheeling Steel Corp.

A Field Engineer from the Fuel Department covers open-hearth furnace activities and coordinates the distribution and production of the oxygen-manufacturing facilities with the requirements of the open-hearth furnace. Full-time instrument-repair service is maintained, as is waste-gas analysis, furnace-draft and infiltration tests, and other work for improving furnace operation. The usual procedure is to run waste-gas analysis after the first ten heats on a furnace campaign; any adjustment necessary to compensate for air infiltration then is set on the fuel-air ratio controller. During the rebuild, all recorders are checked for calibration accuracy. Waste-gas analysis is scheduled by the Field Engineer each week. Each furnace is checked at least four times during a campaign. The results are reported to the Assistant Open-Hearth Superintendent and the Assistant Chief Combustion Engineer.

Checker cleaning is scheduled by the Field Engineer each week, and draft surveys are made and reported to show checker cleanliness. The Field Engineer, under the direction of the Assistant Chief Combustion Engineer, follows up all new installation, experiments, and tests. The Instrument Repair Foreman assigns personnel to the open hearth for around-the-clock coverage.

A series of "Combustion Advice" letters issued by the Fuel Engineering Department to the furnace-operating personnel contributes to the training program for the full utilization of the instruments and controls. These letters explain the proper use of the control equipment, interpret the indicator and recorder readings, and advise methods of securing desired furnace results.

Results

The installation of furnace instrumentation and the application of combustion oxygen took place concurrently at the Steubenville Works Open-Hearth furnaces. The combined effect has been a decided increase in production, a reduction in fuel consumption, and an increase in checker life. General refractory life in the furnace—roof, front-wall, etc.—has not been affected adversely. The use of combustion oxygen and its control has had the beneficial effect of completing combustion in the furnace. This has decreased both the erosion on endwalls, sidewalls, and slag pocket walls, and the fusion of checker brick. Checker brick are still in good condition at the end of 1,500 heats, whereas formerly a large portion of the checker brick was replaced after 300 heats.

The fuel consumption for 1950 was 13.65 percent under 1947 figures and 15.08 percent under 1949 figures. Production increased and fuel decreased steadily, as shown in Fig. 13.

The average production per furnace hour, charge to tap, was 14.3 tons in 1949, whereas the average for 1950 was 15.6 tons, with a maximum of 16.9 tons per furnace hour in October. The production rate in January, 1951, was 17.06 tons per furnace hour for a total shop production of 121,475 tons. The record monthly tonnage in 1950 was 117,646 tons as compared to the previous record of 102,452 tons in March, 1949.

Fuel consumption has declined steadily to a recent low of 3,389,653 Btu. per ton. Oxygen consumption during the record month of October, 1950, was 95 cubic feet per ton for decarbonization, and 492 cubic feet per ton for combustion. Therefore, the installation of measurement and control instruments has been justified. It should be possible to increase production by 30 percent and reduce fuel consumption by 20 percent, as is shown by comparing January figures with the previous base of 90,000 tons per month. Increasing the hot-metal charge from 45 to 60 percent accounts for 10 percent of the increase, while the use of combustion and refining oxygen accounts for 15 percent of the benefits derived from the program instituted to increase production. The instrumentation has contributed about 5 percent of the addi-

tional tonnage and has facilitated handling of the combustion oxygen.

Conclusions

The drawbacks incurred in the original installation and the possibilities of improving and adding to the control system should be mentioned.

The original atomizing steam-oil ratio control was a proportional straight-line control which was not suitable for developing flame characteristics desirable at certain stages of the heat. Therefore, manual air-loading of the atomizing-steam valve was resorted to. An automatic steam-oil ratio controller similar to the fuel-air ratio controller is needed so that an excess or deficiency setting of the steam could be used at any oil flow to develop desired flame conditions.

The automatic reversal based on radiation signals from the top of the checkers led to excessive reversals due to erroneous temperature readings, which were caused by atmospheric conditions in the checkers. A reversal system based on checker-temperature difference and commanded by thermocouples in the checker brickwork will be investigated in the near future. This will be interlocked with the automatic time reversal so that the furnace will reverse at a given checker temperature difference or at a preset time.

A desirable addition might be a controller for the temperature of the metered air to the furnace. Temperature changes of zero to 100 degrees F. during the various seasons of the year can cause a 10 percent change in the weight of oxygen delivered to the furnace. One method of compensating for this difference might be an automatic adjustment of air input from continuous waste-gas analysis.

Roof-temperature control has been applied widely in the industry. Although the lag between the throttling of the fuel and the effect on furnace performance reduces the value of this control, the use of a roof-temperature recorder as a warning device is desirable.

Automatic control of bath temperature is an interesting study when all of the variables are considered. At present the measurement of bath temperature contributes to steel quality, ladle life, yield, mold and stool life, etc. The type of instrument used for determining bath-metal temperature is largely an individual shop problem, depending on shop layout, type of personnel available, and grades of steel produced. The Wheeling Steel Corporation has experimented with the open-end blow-pipe radiation unit. Similar tests with a thermocouple bath-temperature unit will be made.

The control system described was carefully planned and thoroughly engineered before installation. The results obtained, almost from the start of operations, justified the procedure.

Acknowledgements

The authors acknowledge their thanks to the Wheeling Steel Corporation for allowing these data to be presented for publication. Mr. K. Ketcham of the Fuel Engineering Department and others in the Operating and Metallurgical Departments contributed to the contents and reviewed the text.

Instrumentation Minimizes *the* Welding Variable

By J. HEUSCHKEL, Westinghouse Research Laboratories, East Pittsburgh, Pa.

The variables associated with welding processes, together with the instruments which measure and control the variables, are described. For electric resistance welding, the variables are welding force, electrode motion, surface resistance, dynamic resistance, applied voltage, current, heat, and temperature. Arc-welding processes, gas-welding and brazing, thermit welding, and post-welding instrumentation are discussed.

Introduction

WELDING involves the application of intense heat to the parts in the immediate regions involved, usually to the point of fusion of the local steel surfaces. Rate of application and extraction of the heat are important variables.

Welding is an individualized procedure in that joints are produced at tens of thousands of individual stations in thousands of plants and factories. Figs. 1 and 2 show the large number of different processes and the temperature relations. The welding heat is derived from electric resistance, electric arc, gaseous combustion, or from the chemical reactions of solids, as classified in Fig. 2.

The prevention of appalling losses in man-hours and dollars from duplication of quality-control efforts requires the establishment of means for accurately describing how a satisfactory weld is made with any particular combination of process, metals, and joints. This cannot be done orally or in writing unless instruments for measurement of the essential variables are available in both the originating and the duplicating stations.

This discussion describes the broad problems, reviews the general availability of adequate instruments, and points out certain areas where deficiencies still exist. A few unique devices are described.

Classes of Instrumentation Problems

For some processes, the measurement precision required is not great. The areas of use of instrumentation in the welding industry falls into three broad classes:

1. *Prewelding*, that is, measurements prior to welding, including the welding equipment, controls, accessories, and gases that enter into the processes. This may be considered as the trouble-preventive approach.

2. *Welding*, including a determination of the values of each of the essential variables—and of their *uniformity*—during the making of the weld. These variables involve forces, speeds, currents, voltages, liquid- and gas-flow rates, and times. This may be considered as the direct approach which supplements, but does not eliminate the need for, prewelding.

3. *Postwelding*, including a determination of weld and joint composition, and of their physical and metallurgical characteristics. This may be called the indirect approach which, at least theoretically, is unnecessary under ideal conditions. If it always was known with reasonable certainty that suitable materials and equipment were used in conjunction with proper procedure, this third category would never be needed in production. However, this expensive postwelding inspection is commonly specified because of lack of certainty, a skepticism having some merit where no instrumentation is available during either the initial or application operations.

When equipment and procedure conditions are known, experienced personnel can produce suitable welds by using established procedures without knowing the actual values of the essential variables. For example, Fig. 3 shows sections of two spot-welds in ⅛-in. steel, both of which are unsatisfactory. Sample A has incipient fusion because of inadequate heat. Sample B has excessive fusion because of excessive heat. A properly made weld in the same sheet is shown in Fig. 4. In order to understand the differences in operational practices which produced the three different welds, we require instruments to measure the pertinent variables.

There are production conditions where satisfactory welding is being performed continuously without instruments for measuring the variables, but it is impossible to describe exactly how these

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welds are being made. Furthermore, one cannot evaluate the margin of safety within which those operations are being conducted.

Prewelding Instrumentation

It often is true that the properties of the final welded product are determined largely by the inherent characteristics of the steel. Therefore, the steel-making and welding industries are mutually interested in control of steel quality and in the successful use of instrumentation. Witness the widespread interest in "weldability." Uniformity of metal is important. It is possible to weld satisfactorily a composition which ordinarily reacts detrimentally—when the welding engineer knows and can compensate for the characteristics. On the other hand, a uniform and relatively insensitive composition and temper can be harmed by unsatisfactory welding (Fig. 3).

Welding equipments, for all processes, are essentially energy-conversion systems. Electric-resistance and arc-welding machines, for example, derive their activating power from primary sources. It is recognized that the design and constructional features of welding machines are important to the performance of the processes; witness the standards established by NEMA and RWMA.

The manufacture of welding control systems and accessories also requires the use of adequate instruments—ammeters, voltmeters, electronic tube-checking units, resistor-calibration devices, and oscilloscopes.

The manufacture of welders' glasses must be controlled so that excessive amounts of the harmful infrared and ultraviolet rays do not penetrate to the eyes of the operator.

Welding gases must be of a suitable order of purity. Excessive amounts of moisture or other impurities such as nitrogen may impair the properties of the welds. A recent development is the establishment of "welding-grade" inert gases. Purities of these gases must be controlled and checked. The mass spectrometer is an invaluable instrument for such checking.

All in all, the instrumentation involved in the development and construction of the equipment and materials used in welding is a fairly lengthy subject, but is beyond the scope of this article.

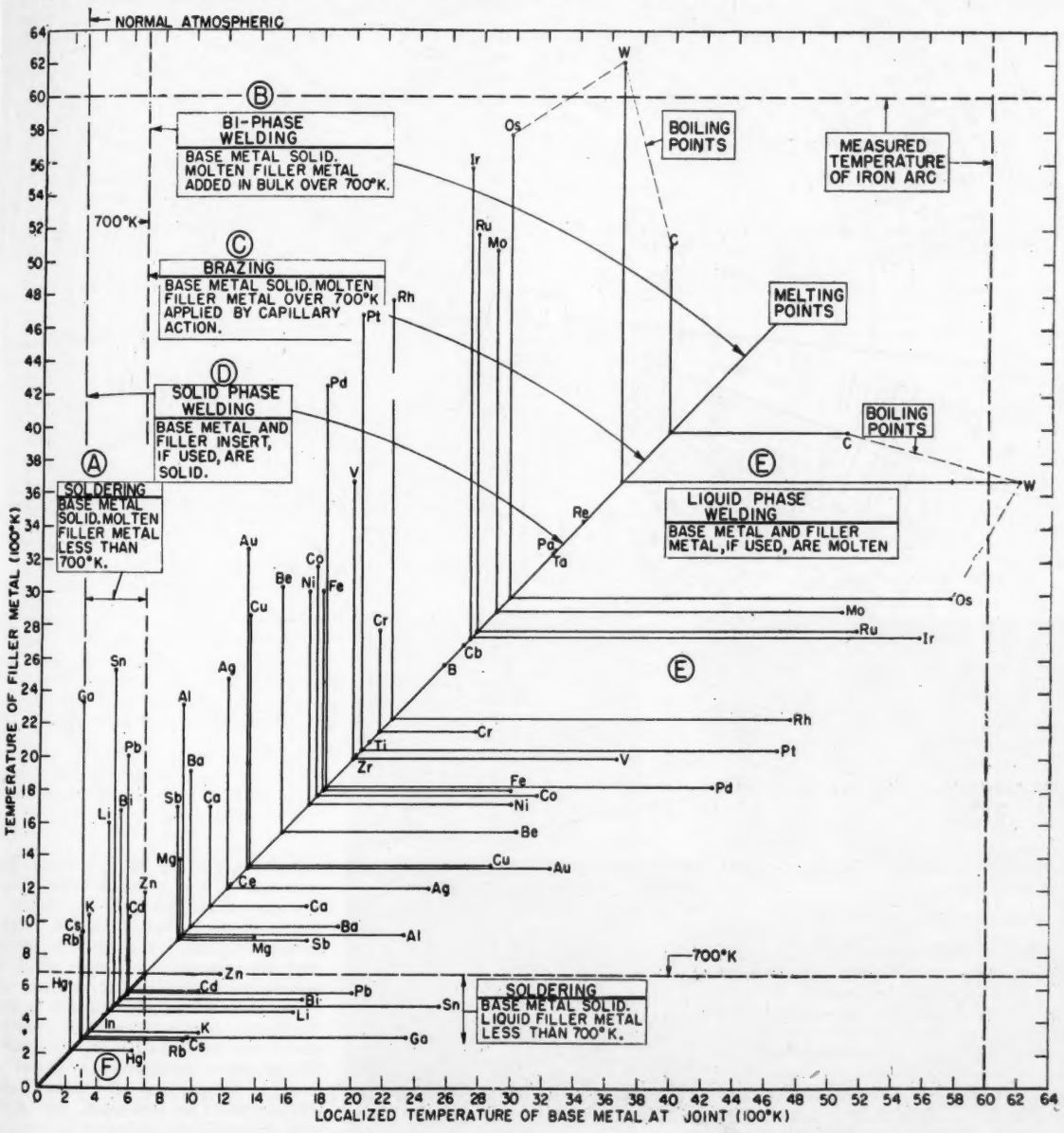

NORMAL ATMOSPHERIC
BI-PHASE WELDING
BASE METAL SOLID. MOLTEN FILLER METAL ADDED IN BULK OVER 700°K.
700°K
BRAZING
BASE METAL SOLID. MOLTEN FILLER METAL OVER 700°K APPLIED BY CAPILLARY ACTION.
SOLID PHASE WELDING
BASE METAL AND FILLER INSERT, IF USED, ARE SOLID.
SOLDERING
BASE METAL SOLID. MOLTEN FILLER METAL LESS THAN 700°K.
BOILING POINTS
MEASURED TEMPERATURE OF IRON ARC
MELTING POINTS
BOILING POINTS
LIQUID PHASE WELDING
BASE METAL AND FILLER METAL, IF USED, ARE MOLTEN
700°K
SOLDERING
BASE METAL SOLID. LIQUID FILLER METAL LESS THAN 700°K.
TEMPERATURE OF FILLER METAL (100°K)
LOCALIZED TEMPERATURE OF BASE METAL AT JOINT (100°K)

Fig. 1. Temperatures in soldering, brazing, and welding.

Welding Process Instrumentation

As welding, brazing, and soldering involve the application and dissipation of heat to the parts which make up the joint, the measuring problem involves heat input and rate of heat dissipation. For convenience, the instrumentation will be explored within the broad categories of the process classifications of Fig. 2.

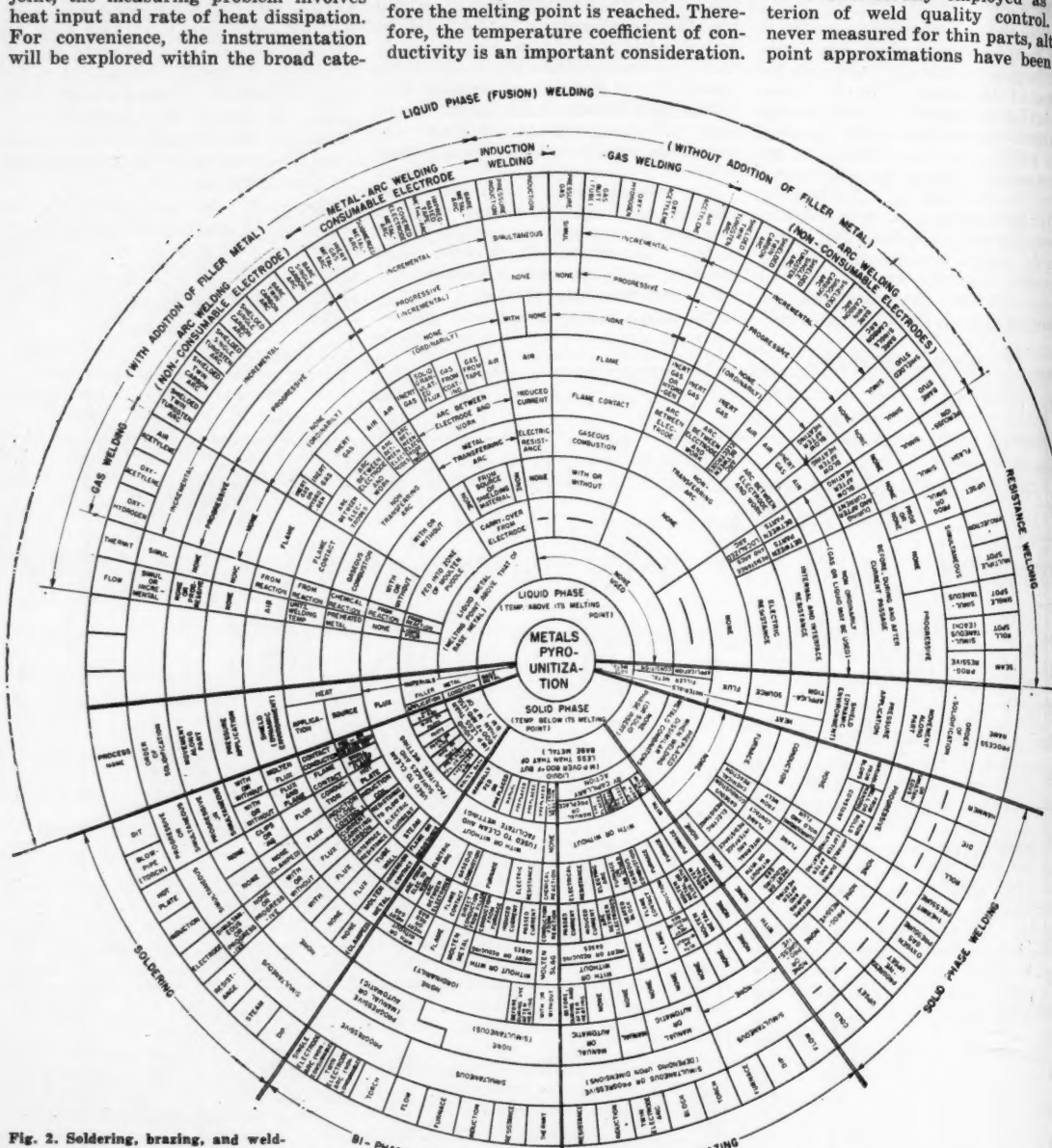


Fig. 2. Soldering, brazing, and welding processes.

Electric Resistance Welding

Electric resistance welding depends on the heat derived from the passage of high-density electric currents through the parts being joined. Electrical conductivity, or its reciprocal—resistivity—is one of the fundamental characteristics of metals. Of the common pure metals, silver has the lowest electrical resistivity—1.59 microhms per cm. at 0 C., and titanium has the highest—80 microhms per cm. Iron, the basic ingredient of steel, has a resistivity value of 9.71 at that temperature. Resistivity increases with alloy content, cold work, and temperature; the value of 9.71 for iron at 0 C., increases to over 100 before the melting point is reached. Therefore, the temperature coefficient of conductivity is an important consideration.

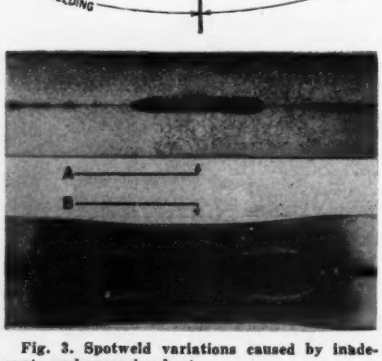


Fig. 3. Spotweld variations caused by inadequate and excessive heat.

Although the fundamental variable in resistance welding is temperature and rate of change of temperature in the localized parts, temperature is never successfully employed as a criterion of weld quality control. It is never measured for thin parts, although point approximations have been made experimentally for heavier parts. Temperature is not measured for several reasons—first, the rate of change of temperature is too fast for thermocouple response; second, the induced magnetic signal is larger than the temperature differential signal; and third, it is extremely difficult to place the thermocouple where it is needed to detect the temperature in thin sheets. Temperature gradients are steep, and a slight misplacing of pickup probes, if they could be developed, would provide misleading results.

For the present, the most suitable

criteria of temperature is obtained by use of the metallurgical thermometer, which employs the concept that a known temperature-time cycle produces a known hardness, microstructure, or isotherm pattern.

Unfortunately, it is not possible to use this approach, except by sectioning a completed weld. The inability to follow directly and precisely the strictly localized dynamic time-temperature cycle during the formation and cooling of the weld is still a blind spot in the precise study of the welding processes. For production control, however, this is not a strong deterrent. By preselecting schedules which have minimum variations in procedure, it is possible to produce high-quality welds with a minimum of production instrumentation, assuming the machines are originally calibrated and are periodically checked for performance. Optimum schedules for welding force, welding time, welding current, and electrode diameter are shown in Fig. 5 A, B, C, and D, respectively, for a 0.095-in. low-carbon steel.

The heat, H, developed by resistance heating is given by the equation:

$$H = kI^2Rt,$$

where I is the current through ohmic resistance path R for time t. Because resistance R is low in magnitude, current I is necessarily high—from 100 to 100,000 amperes. The current can be decreased at the expense of time. However, efforts to minimize current to an excessively low amount result in the establishment of a state of thermal equilibrium between heat build-up and dissipation, with the temperature too low for the formation of a satisfactory weld. Measurements vital to an understanding of these processes, therefore, involve current, resistance, and time, or their effective products.

In resistance welding, brazing, and soldering, a complicating factor is the presence of the initial discontinuity between the parts being joined, including the interfaces of the ultimate joint. The heating current must traverse a minimum of three pairs of contacting surfaces, the interface resistance of which is not constant (Fig. 4). More interfaces are involved for multiple-thickness combinations.

Welding Force.—To reduce this initial interface resistance to a minimum, to confine the molten metal, and to assure nugget solidification as a unit, force is applied to the current-carrying electrodes (Fig. 4). This force may be from a few pounds to about 20,000 pounds, depending on the material composition and dimensions. Force thus becomes a fourth basic variable. But static force is not the same as the dynamic force if friction or inertia within the machine components is high. For prewelding machine-calibration it is desirable, although not mandatory for steel, that the inertia, friction, and motion characteristics be known. This is more important for projection, butt, and flash welding.

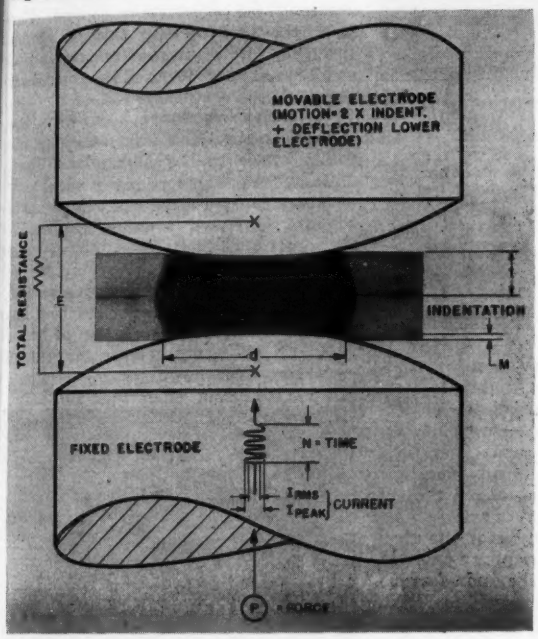


Fig. 4. A proper spotweld, showing the set-up and variables.

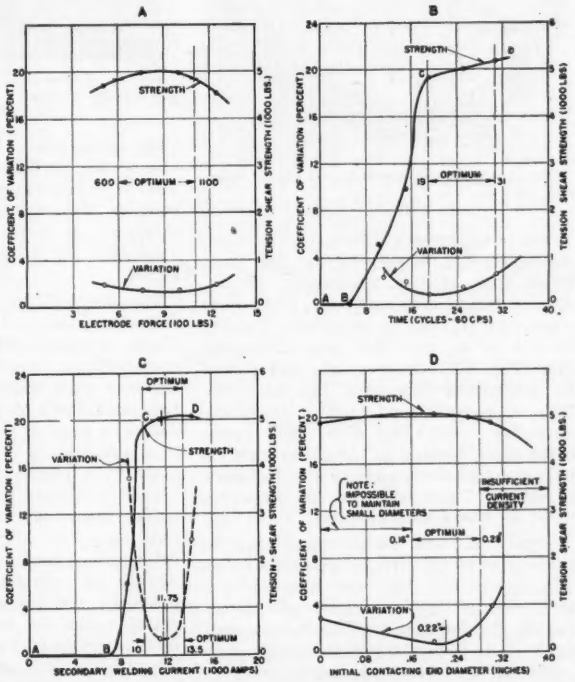


Fig. 5. Curves of spotweld strength and variability versus force, time, current, and electrode diameter.

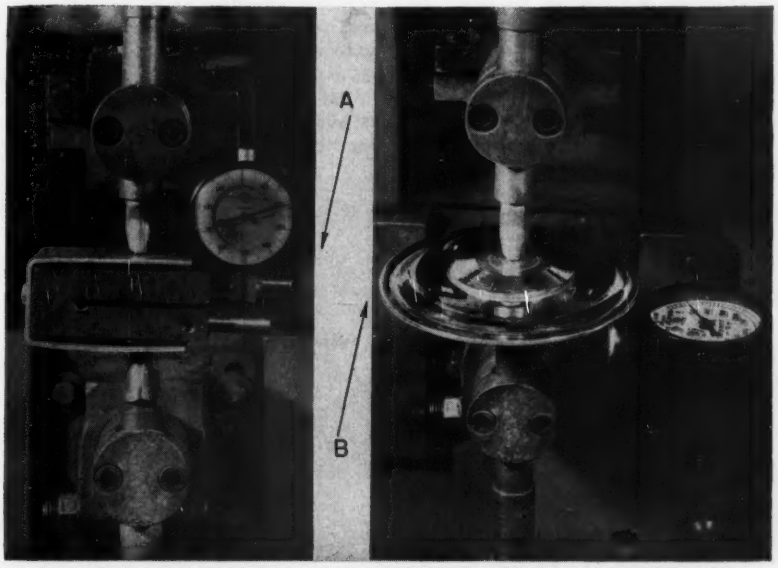
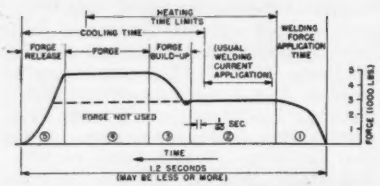


Fig. 6. Instruments for measurement of static forces: A, force bar; B, pressure disk.



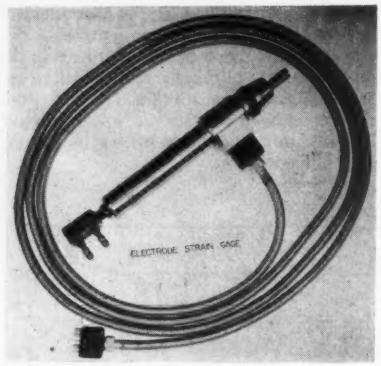


Fig. 7. Strain-gage electrode and typical force-time record.

The compressive force on the electrodes of Fig. 4 may be applied from lever, cam, spring, pneumatic, or hydraulic sources. In any case, the actual static force can be obtained directly by use of a force bar and calibrated dial (Fig. 6A). At least one pad should be electrically insulated. The force-bar type of gage is preferred to the pressure-disk type (Fig. 6B). Both types often are deficient in that they require an opening between electrodes for gage insertion. There is room for improvement in these instruments.

Dynamic force measurement can be made also by the arrangement shown in Fig. 7, which uses the now-common strain gage, an amplifier, and a recorder. The steel-braid shielded coaxial-cable leads reduce magnetic-signal pick-up from the electromagnetic field of the welding current.

Motion of Electrode.—Dynamic motion can be recorded by a signal from a fixed coil and a movable core, as shown in Fig. 8. A typical motion record (Fig. 9) plotted against time shows approach velocity, rebound, occurrence of indentation, and time and velocity of electrode separation. In Fig. 9 the lower line of the envelope trace describes the motion of the upper electrode with respect to the lower one. Strain gages attached to lever devices have been used also for studying projection collapse.

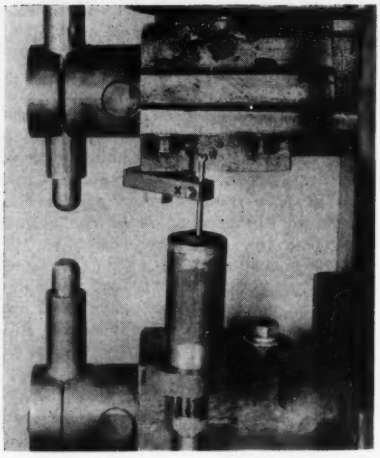


Fig. 8. Differential transformer mount on spotwelding machine.

Inability of the movable electrode to follow-up the collapsing metal is likely to cause difficulty in any resistance-welding operation, but this item becomes most important in the projection and flash-welding operations, insofar as steel is concerned. Therefore, it is prudent to know in advance that a machine purchased for such a project is calibrated and proved satisfactory before usage. Fortunately for the steel industry, the rigid requirements in follow-up speed of the non-ferrous metals for simple spot-welding have produced low-inertia high-speed heads suitable for the welding of steel. The motion device of Fig. 8, or some equivalent instrument, greatly simplifies the task of machine calibration for such purposes. Insofar as is known, such motion studies are unnecessary in production.

Surface Condition and Resistance.—Initial surface condition of material, as evaluated from resistance, can be described by the use of the instrument shown in Fig. 10. Any desired electrode shape and composition can be employed with variable force and current, and ohmic resistance can be read directly on the dial.

As surface oxides and other foreign material contaminate the contacting ends of the electrodes, clean surfaces are desired. For this reason, pickled and oiled or cold-finished surfaces normally are specified for resistance welding in production. Variations in surface can be evaluated in terms of total resistance, which essentially means surface resistance. The unit shown in Fig. 10 is a laboratory model suitable for such purposes. A simpler unit could be designed for production control. For steel, the surface resistance is seldom specified, but is ordinarily low and is progressively lowered by increased force, as shown in Fig. 11.

Dynamic Resistance.—As with the force systems, there is a difference between static and dynamic conditions. Metallic resistance changes with temperature. A spot weld in 0.010-in. sheet may be completed in one cycle of a 60-cps. current. Therefore, the *average* rate of temperature rise may be as much as 164,000 degrees F. per second, even assuming the nugget reached, but did not exceed, the melting point of 2800 F. Therefore, rapid changes in resistance occur.

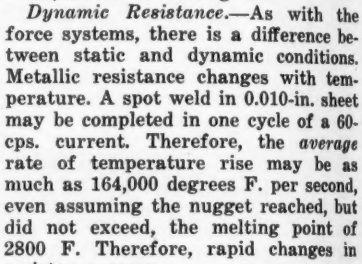


Fig. 10. Laboratory surface-resistance instrument.

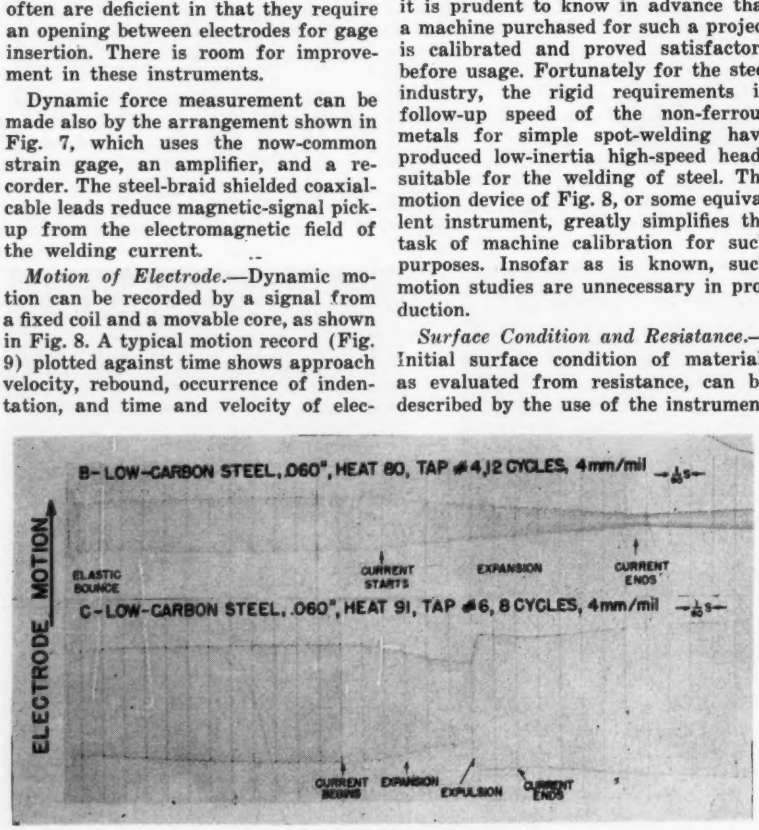


Fig. 9. Typical oscillogram of motion.

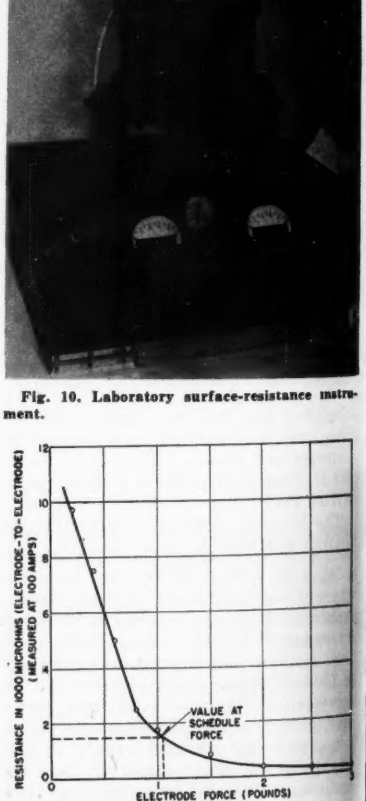

RESISTANCE IN 1000 MICROHMS (ELECTRODE-TO-ELECTRODE) (MEASURED AT 100 AMPS)
VALUE AT SCHEDULE FORCE
ELECTRODE FORCE (POUNDS)

Fig. 11. Curve of contact resistance versus force.

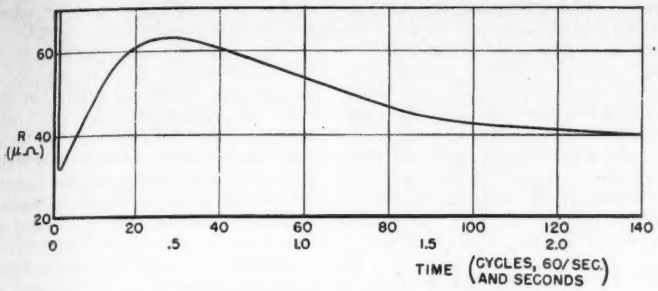


Fig. 12. Resistance-time curve for a steel spotweld.

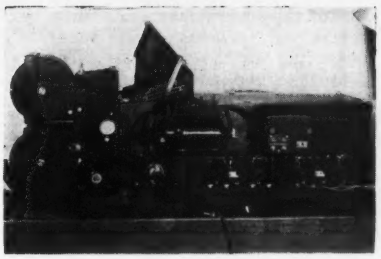


Fig. 13. Magnetic oscillograph.

Total dynamic resistance during welding, either electrode-to-electrode, electrode-to-sheet, or sheet-to-sheet, cannot be measured directly at this time. Several attempts have been made to provide a continuously recording resistance evaluation device, but none has been succesful. This value can be calculated from the E/I ratio if both E and I are determined accurately. Fig. 12 shows a curve so calculated for a ⅛-in. carbon-steel spot-weld, with 1500-lb. force and 12,000 amperes.

Voltage.—Dynamic voltage across the two electrodes can be recorded by the magnetic oscillograph (Fig. 13) or indicated by a direct-reading instrument for average observation (Fig. 14). It is important that the inductive pickup be small or that it be counterbalanced by an internal loop. The preferred means is to conduct the leads internally through the axes of the two electrodes.

Currents.—Resistance-welding currents may vary from a few up to 100,000 or more amperes. The most common method of measurement is by use of current transformers surrounding a suitable portion of a conductor. This can be done on either the primary or secondary windings of the transformer. Commonest practice involves measurement of the primary because of accessibility. When current is measured in the secondary circuit, an iron-core toroid can be employed. For higher currents an air-core toroid, composed of a group of individual coils, is superior because it is free of magnetic saturation. On shallow-throat spot and seam welders, on multiple-electrode spot-welders, and on projection welders, it often is impossible to place a pickup coil or current transformer around the appropriate current-carrying parts of the secondary circuit.

No direct-reading current indicator gives the precise value for the current because that value is not constant throughout the formation of a weld. Current flow may be continuous or it may be intermittently interrupted, as in pulsation, spot, or seam welding.

Secondary current (I_s), neglecting welder transformer losses, can be calculated from the primary current (I_p) multiplied by the ratio of the primary turns (T_p) to the secondary turns (T_s):

$$I_s = I_p \quad (T_p/T_s).$$

The secondary voltage (E_s) is the primary voltage (E_p) divided by the turns ratio, which is therefore derived from:

$$\text{Turns Ratio} = E_p/E_s.$$

For these measurements, voltmeters with a capacity from 1.25 to 3.0 times that of the reading are used. Measurements are made with welding dies or electrodes separated by insulating material. Primary and secondary readings are taken simultaneously. As there are variable welder transformer losses, calculated secondary currents may be in error from 5 to 10 percent. Therefore, the transformer characteristics must be known.

Oxides are highly resistive to current passage at normal temperatures, but become partial conductors at elevated temperatures. Resistance can be decreased by increased pressures, as shown in Fig. 11. Efforts have been made to employ a combination of these two features by using semispherical domed electrodes, high initial forces, and a low rate of rise of current, as shown in Fig. 15. For specifying such conditions, one cannot use a single value of current, but must refer to rate of rise of peak, number of cycles to maximum, and magnitude of maximum current.

Low-frequency a-c. and d-c. systems can be employed also. Here again, conventional ammeter readings are valid only for waveshapes which have a substantially uniform magnitude, as in items 3 and 4 of Fig. 16. As it is probable that non-uniform waveshapes will come into more common use in the future, steps should be taken to clarify the best means for recording, measuring, evaluating, and describing the currents used for making welds with these systems.

Heat.—The welding heat can be approximated by:

$$\text{Heat} = IET.$$

Several devices have been employed for measuring the product of some of the variables entering into the heat equation. These have included I^2T indicators and watthour meters. These products cannot be indiscriminately accepted as an accurate evaluation of quality of weld for several reasons. First, the energy required to make a given nugget is different for a short-time weld than it is for a long-time weld because of differences in thermal losses. Second, there is the matter of current flow path. In multiple-welded joints, as ordinarily used in production, current tends to shunt through previously-made welds. For this reason it is preferable to use established sched-

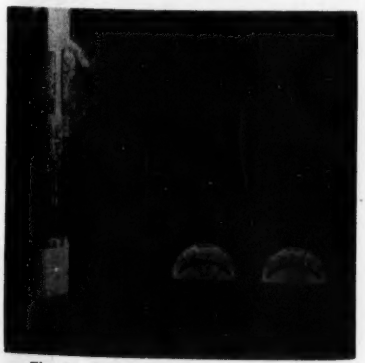


Fig. 14. Direct-reading a-c. voltmeters.

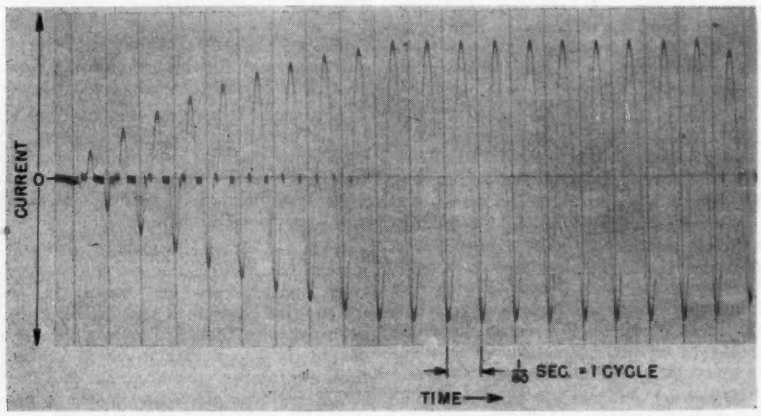


Fig. 15. Slope-controlled 60-cps. current waveform obtained from an oscillograph.

ules of the several variables for a particular weld spacing, while separately measuring all the variables except resistance, which usually is ignored because no practical device exists for its measurement.

Other Factors.—For high-quality production, the cooling-water flow-rate and temperatures should be known also. This requires a flowmeter and a thermometer. Gages for checking air or hydraulic pressure sources are also necessary. Force on the weld varies with line pressure for such machines and an erratic pressure source can produce erratic weld quality. Suitable pressure gages to permit the welding supervision to detect such sources of variation before they become a production problem are essential. The uniformity of the primary line voltage, which may be 440, 2400, or 3200 volts, should be known because variation in line voltage influence the secondary current delivered to the weld zone. For measurements above 750 volts, a step-down transformer should be used with an electrically-isolated secondary which has one side grounded. For primary line-current measurements, a current transformer and a pointer-stop ammeter should be used.

Resistance butt-welding involves the same electromechanical variables as spot welding. Seam welding also offers the same problems and solutions, except that current flow is commonly continuous.

The variables in projection welding are the same as those for spot welding, except that ability of the movable electrode to "follow-up" the collapse of the molten projection is important. It also is common practice to weld several projections at one time; as parallel current flow-paths exist, the measurement of current within individual welds cannot be made.

Current "flow times" may vary from half a cycle to several hundred cycles, depending on material thickness. When using a recording magnetic oscillograph in the laboratory, the time interval is visible on the trace (Fig. 16). With synchronous controls, current is initiated and terminated at the zero points of current, thus full cycles or half-cycles always are recorded. For production checking and development purposes, direct-recording cycle-counters and cycle trace-recorders are available.

Arc Welding

Arc-welding processes derive their concentrated heat source directly from the electric arc between two electrodes, one of which generally is the workpiece. This discussion is confined to the consumable steel-electrode, or metal-arc, processes; and to the non-consumable tungsten-electrode process with an inert-gas shield. In both processes, either alternating or direct current can be used; and the electrode movement may be either manual or automatic.

Metal-arc Processes.—The two basic measurable and controllable variables of manual arc-welding are the arc current and voltage. Burn-off rate of electrode is a function of wattage. Production rate of welding, as well as quality of welded products, can be influenced by the burn-off rate. For each combination of base-metal mass and disposition, and selected electrode, there is an optimum current operating range. Rough production welding seldom is controlled by use of any instrument check-up. However, there always is available, in lieu of an ammeter, the criterion of a predetermined electrode melt-off rate. This rate can be established by a marked length of wire and a stop watch.

It is possible to define an ampere as the amount of current that melts a specific amount of electrode of known characteristic in unit time. It is desirable, however, to have reference ammeters and voltmeters available. Current flow is essentially continuous in arc welding, and the ammeter can be of three types—the dynamometer, the d'Arsonval, and the iron-vane type. The currents can be from 5 to 1200 amperes. A multi-range instrument can be used with some sacrifice of accuracy. The dynamometer ammeter suffers from two deficiencies—it is sensitive to surrounding magnetic fields; and it requires power for its operation. However, this is not generally important.

A simple tong-type ammeter (Fig. 17) is useful for checking currents at individual stations. No connections are required. Arc voltage must be measured from leads attached to the work and the electrode holder.

Both a-c. and d-c. ammeters and voltmeters can be of the recording type. Such instruments are useful in the training of operators and in the evaluation of electrodes. However, records ordinarily are not required in production, except for special cases, and they often are worthless for research purposes because the response is too slow. They do reveal if steady or unsteady arc conditions are encountered.

The magnetic oscillograph is much more useful for precise studies. The details for uniform operation of an a-c. metal-transferring arc can be shown clearly. However, even the magnetic oscilloscope is too slow in response to reveal the details of the characteristic half-cycle reignition voltage-spike, which is recorded only as a faint single line-burst on the trace. The response is adequate to record half-cycle rectification, wherein, for a 1/120-second interval, voltage goes to open-circuit value and no current is conducted. It is sufficiently accurate, also, to show arc-shorting conditions in detail. When the arc shorts, the voltage drops to a low value and the current surges to a maximum, depending on machine characteristics. A similar set of conditions exists for d-c. arc welding (Fig. 18). The magnetic oscillograph is, therefore, a useful instrument for research and development work; but it is too expensive, complicated, and time-consuming to have value in production.

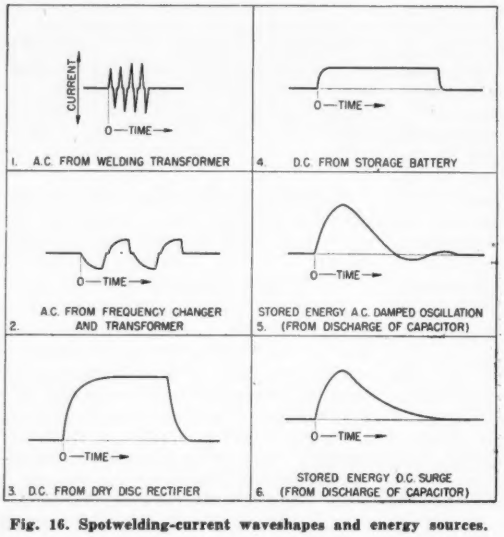

CURRENT
0—TIME
1. A.C. FROM WELDING TRANSFORMER
4. D.C. FROM STORAGE BATTERY
A.C. FROM FREQUENCY CHANGER AND TRANSFORMER
2.
STORED ENERGY A.C. DAMPED OSCILLATION
5. (FROM DISCHARGE OF CAPACITOR)
3. D.C. FROM DRY DISC RECTIFIER
STORED ENERGY D.C. SURGE
6. (FROM DISCHARGE OF CAPACITOR)

Fig. 16. Spotwelding-current waveshapes and energy sources.

Fig. 17. Tong-type ammeter.

Submerged Metal-arc Process.—In the submerged metal-arc process, welds are produced under the protective blanket of a granulated flux. The wire feed is electromechanically related to the arc voltage. Other variables are arc current (100-1500 amp.), and carriage speed (10 to 200 in. per min.). Commercial machines include panel ammeters and voltmeters, which should be checked periodically against standard instruments.

Tungsten Electrode with Inert-gas Shield.—Within recent years, the tungsten-steel argon-arc or helium-arc process has found more applications within the steel industry. Fig. 19 illustrates an unusual butt joining of two ends of a steel sheet with a thickness of 0.006 inch. The desired product was a strong flush joint without overlap. Only a few years ago, arc welding could not

have been considered for such an application. How was the weld made? In order to describe the procedure so that the results can be duplicated, one must specify, in addition to type of equipment and joint preparations:

Variable	*Instrument*
Electrode diameter	micrometer
Gas flow-rate	flowmeter
Gas purity	mass spectrometer
Travel speed	rule and stopwatch or tachometer
Open-circuit voltage	voltmeter
Arc voltage	voltmeter
Arc current	ammeter

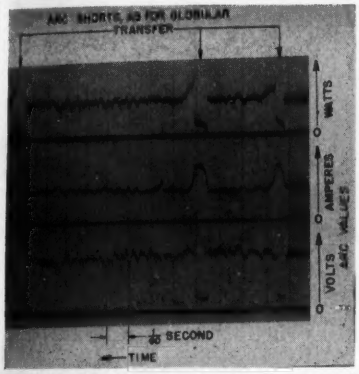


Fig. 18. Ampere, volt, and wattage traces of d-c. metal-transferring arc on steel as recorded by an electromagnetic oscillograph.

Additionally, one is interested in knowing whether or not the arc is steady under the conditions employed. The electromagnetic oscillograph provides this information.

As the magnetic oscillograph cannot follow the rapid fluctuations in voltage at current reversal, a higher speed

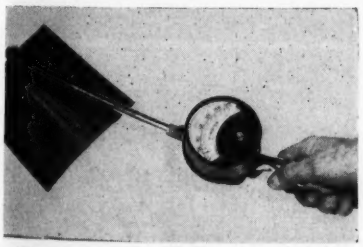


Fig. 21. Contact pyrometer for checking preheat temperature.

cathode-ray oscilloscope is useful, particularly the dual-beam type shown in Fig. 20. The oscilloscope can show voltage and current traces simultaneously. For the permanent record it is necessary to photograph the screen image. The newer direct-printing camera facilities are expected to be a boon to the field of welding instrumentation and study.

Normal-motion and high-speed cameras for arc-action studies are also useful, particularly when synchronized with oscilloscopic recordings. For best results, intense external light sources are required.

In arc-welded production, preheating is sometimes specified to retard the cooling rate, reduce hardness, and minimize the likelihood of cracking. For checking preheating temperatures one may use various techniques, including the use of wires with known low-temperature melting points; or one may use direct-reading pyrometers, as shown in Fig. 21. Such instruments can be recalibrated periodically against a furnace under accurate control. Stepless ranges up to 1200 deg. F. are available.

Gas Welding and Brazing

In the gas processes, wherein the heat is derived from the combustion of a fuel gas in the presence of air or oxygen, no instrumentation is involved.

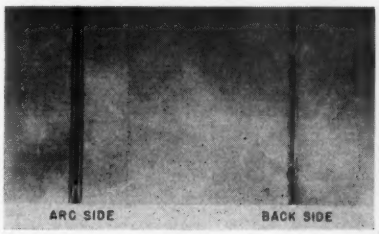


Fig. 19. Tungsten-steel-argon arc-welded butt-joint in 0.006-in. sheet.

Pressure regulators and torches for applying the flame and for adjusting the mixture of the gases usually are considered to be equipment, not instruments. These units do have built-in pressure gages (Fig. 22), which the operator uses for indicating the relative volumes of the two gases supplied

Fig. 22. Standard reduction valve with integral pressure gages and flowmeter.

to the mixing chamber and the continued availability from the primary source, which may be a pipeline or a pressure tank. The trained operator can tell from the appearance of the flame whether an oxidizing, neutral, or carburizing flame is being applied. Fig. 22 also illustrates the gas flowmeter, which is used in inert-gas arc-welding processes.

Thermit Welding

In thermit processes the heat is derived from the exothermic chemical reaction between iron-oxide and aluminum. No instrumentation is ordinarily involved.

Postwelding Measurements

A finished weldment completed under known and controlled conditions is satisfactory for its designed purpose. The mystery and uncertainty is removed by providing experienced personnel with adequate instrumentation.

During research and development, and in some instances to satisfy code or specification production-requirements, an evaluation of the welds or welded joints can be made. Such evaluations use instruments of the metals-testing field.

For detection of possible flaws, cracks,

Fig. 20. Dual-beam cathode-ray oscilloscope.

and voids, the instruments used can be: (1) X-ray, (2) gamma ray, (3) "Supersonic Reflectoscope," (4) "Zyglo," (5) "Magnaflux," or (6) gaseous leak detectors.

For *chemical analysis*, the instruments are: (1) Wet methods, (2) spectroscopic, or (3) mass spectrometer.

For *mechanical properties*, use is made of: (1) Tensile testing devices, (2) bending testing devices, (3) shear or torsion testing devices, (4) hardness testing devices, (5) impact testing devices, or (6) fatigue testing devices.

For *metallographic characteristics*, use is made of: (1) Metallograph, or (2) microscopes.

For *other characteristics*, use is made of: (1) Corrosion-testing devices, (2) magnetic testing devices, or (3) creep-testing devices.

Summary

To describe the optimum welding conditions which produce a satisfactory weld, it is necessary to measure the essential variables. Since many different kinds and makes of machines are employed in industry, it is not practical to describe welding conditions in terms of machine settings alone. However, once the essential variables are measured, it becomes possible to describe precisely how the weld is made so that the proper conditions can be repeated. Considerable effort can be invested profitably within the field to make further improvements in the techniques of welding instrumentation.

INSTRUMENT EXHIBITS AT BRITISH INDUSTRIES FAIR, BIRMINGHAM

INSTRUMENT EXHIBITS AT THE PARIS FAIR

My Second Report to *Instruments'* Readers on Europe's Industrial *and* Instrument Fairs

By **RICHARD RIMBACH, Publisher, *Instruments***

As our readers know, it has been a policy of *Instruments* for many years to keep in close touch with the European instrument industry, and to report on significant developments abroad. Last year I visited the major European trade fairs and exhibitions and reported to you—in the September 1950 *Instruments*—on: (1) the state of the European instrument industry, (2) the new instruments, (3) the extent of instrument exhibits and expositions, and (4) the significant differences and similarities between the American and European instrument industries.

This year, I visited the Hanover Fair (April 29-May 8), the British Industries Fair (April 30-May 11), the Paris Fair (April 28-May 14), the French Exhibition of Instruments and Scientific Material (May 11-May 17), the British Gage and Tool Exhibition May 15-May 25), and the British Instrument Industries Exhibition (July 4-14). Once again, here is my report and your pictorial trip to these fairs and expositions.

British Industries Fair

The British Industries Fair was a huge exposition of 2869 exhibitors, representing all phases of British industry. There were 1,028,626 square feet of exhibit space at two locations —London's Olympia and Castle Bromwich, Birmingham. The two exhibit areas were about three and a half hours' travel (by train) from each other.

There were only nineteen instrument manufacturers at the BIF shows because of the First British Instrument Industries Exhibition, held at Olympia, July 4 to July 14. The scientific instrument exhibitors were mainly at the Olympia; the industrial instrument exhibitors were mainly at Birmingham.

The attendance of foreign and domestic buyers at the BIF was about the same as in 1950.

French Exhibition of Instruments and Scientific Material

The French 48th Exposition of Instruments and Scientific Material was sponsored by the French Physical Society and held at the halls of the University of Paris (the "Sorbonne"). There were 130 exhibitors in five halls. The latest British developments in scientific instruments were shown at fifty booths in a separate hall.

Many of the exhibitors were government agencies. A catalog of 340 pages described and illustrated the developments on display.

Paris Fair

The Paris Fair (April 28-May 14) had 10,500 exhibitors who used 2,852,400 square feet of exhibit space. As in England, the number of instrument exhibitors at the gigantic industry-wide fair decreased from last year because of the growth of more specialized trade fairs.

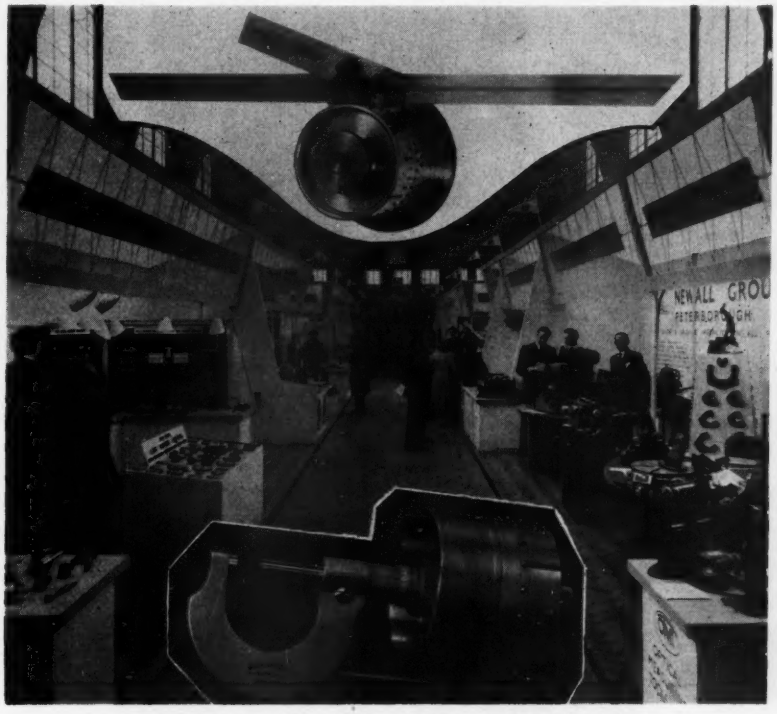
Gage and Tool Exhibition

The Gage and Tool Exhibition was held at New Hall of the Royal Horticultural Society, May 15th to 25th. This was the third Exhibition organized by the Gage and Tool Makers' Association. There were 76 exhibitors of gages and measuring equipment; jigs, fixtures and special tools; special-purpose machines and equipment; and dies, small tools, and diamond tools.

Among the new developments were a Braille reading micrometer and a Braille bevel protractor, which are illustrated above.

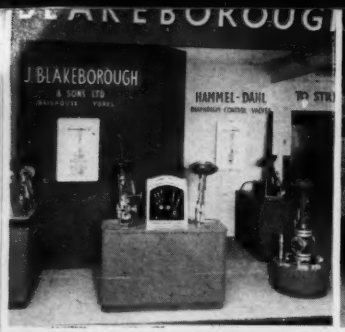
The Braille reading micrometer is based directly on the ordinary micrometer. As the graduations of the ordinary micrometer are too fine to permit a blind person to read with his fingertips, the three fundamental sets of graduations were transferred to three large drums, which gave wider spacing and were numbered in Braille. The blind craftsmen, when taking a reading, revolves the first drum until the measuring faces and the job being measured are in satisfactory contact. Then he runs his finger tips along the single raised zero line on the fixed drum, and past this to whatever raised lines are in line with it on the first and third drum. As these lines are numbered in Braille, he can read the measurement indicated.

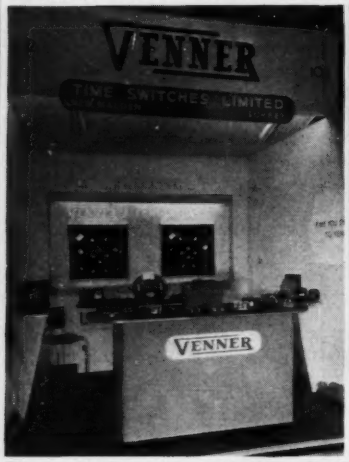
The Braille bevel protractor is similar to the ordinary universal bevel protractor in that the basic mechanism is a blade attached to a rotating drum pivoted in the center of a circular base plate having an outward extension. The desired angle, or the angle being measured, is that between the

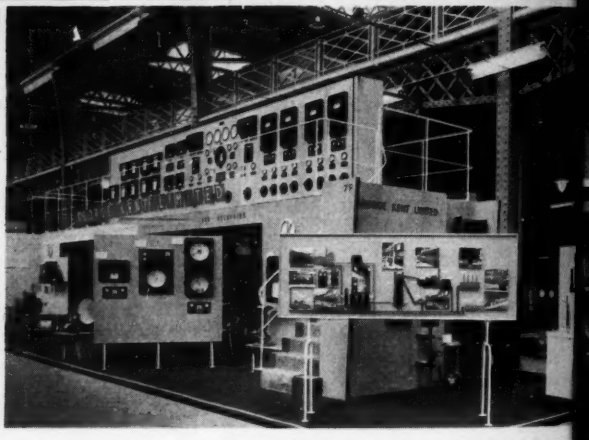


BRITISH GAGE AND TOOL EXHIBITION

Top inset, Braille bevel protractor.
Bottom inset, Braille reading micrometer.







EXHIBITS AT THE FIRST BRITISH INSTRUMENT INDUSTRIES EXHIBITION, OLYMPIA, LONDON

blade and the extension of the base plate.

Immediately over the lower rotating drum are two more drums, which may be denoted as the center drum and the upper drum. The upper drum is divided into 36 divisions, each equal to 0.25 degree. It is marked at every four divisions—that is, at every whole degree. One complete revolution of this drum indicates nine degrees. The divisions are indicated by a raised tooth which can be discerned easily by touch, and the degree markings are in Braille characters. The zero line can be distinguished from the ordinary divisions in that it goes across the drum. This means that, by reference to the raised line of the center drum, it is possible to say by how many degrees or quarter degrees the upper drum is turned. The center drum remains stationary and does not revolve.

British Instrument Industries Exhibition

The first British Instrument Industries Exhibition was held July 4-July 14 at the National Hall, Olympia, London. The exhibit was suggested by the Department of Scientific and Industrial Research, and approved by five British manufacturers' associations:

The Electrical Allied Manufacturers
The Lamp-blown Scientific Glass Ware
The Industrial Measuring and Control Apparatus Manufacturers
Drawing Office Material Manufacturers and Dealers
The Scientific Instrument Manufacturers

There were 143 exhibitors and 43,000 square feet of exhibit space. Each exhibitor spared no expense in producing large attractive booths. The show was well organized under the direction of General Bols. The Exhibition was a complete picture of the British Instrument Industry as the members of the above associations displayed their products.

The Exhibit was opened officially by Minister of Supply Straus, at a luncheon. Here is a significant quotation from his talk:

"Scientific instruments, whose production requires the most highly skilled designers and craftsmen, serve humanity, economic prosperity and security. They are keys to health, wealth and defense. Holding as it does a strategic position in all three respects the industry is rightly protected by the Key Industries Duties, imposed under the Safeguarding of Industries Act, against imports of foreign instruments.

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At one time we were almost completely dependent for some type of instruments on foreign manufacturers, and instrument craftsmanship was in serious danger of decay. Had the decline continued, the disaster might have been beyond repair, for the highest technical precision and the most delicate craftsmanship are precious possessions not soon or easily acquired. If attained at all it is only by prolonged patient, longsighted effort. Experience in the war compelled us to put the industry firmly on its feet, and to-day it is well established. All parties and interests are agreed that the former blunder must not be repeated."

Mr. Mark H. Taylor, President of the Scientific Instrument Manufacturers Association (SIMA) spoke for the Manufacturers. The theme of his speech was that the cooperative effort made by the five trade associations in sponsoring the BIIE should be extended in the interest of the customer, the employee, and the owner. Mr. Taylor continued "I am not unaware that most Industries will submit that they justify special treatment. You will need no reminding of the problems that arise from the shortage of raw materials. We are, as an Industry, concerned with defense, with export and with home requirements—but unlike many other industries we cannot sacrifice the home demand in the interests of the other two, because we provide the very means whereby other industries in this country can increase their efficiency, can implement standardization, can search for new materials, can conduct their research; it is with our products that they can effect fine measurement and increase their productivity by the extension of industrial control."

The Instruments Publishing Company exhibited *Instruments*, *The Instrument Maker*, and our other publications at Stand 157 at the BIIE. At the BIIE, we were the only foreign exhibitor.

Hanover Fair

The Hanover Heavy Industries Fair increased exhibit space considerably above last year. Exhibits covering 1,932,000 square feet were shown by 2645 manufacturers, of which 243 were manufacturers of instruments and devices for measurement, inspection, testing, and control. Industrial and laboratory instruments were displayed by 64 exhibitors, electrical instruments and testers by 43, testing machines by 14, scales and balances by 20, and gage and precision tools by 102.

The booths indicated that the instru-

INSTRUMENT EXHIBITS AT THE HANOVER HEAVY INDUSTRIES FAIR, HANOVER, GERMANY

ment manufacturers are more prosperous than they were a year ago. Delivery quoted by many manufacturers was about four weeks.

Since last year the Hanover Fair had added a new building—the Europa Hall. This hall has the largest clear span in Europe—perhaps in the world. It is 275 feet wide by 510 feet long, and provides an area of 140,000 square feet without a column.

The Instruments Publishing Company occupied Booth 607 in Hall XIV at Hanover. We exhibited *Instruments*, *The Instrument Maker*, and the books published by this company. The Brown Instrument Division of Minneapolis-Honeywell exhibited in Hall IX.

General Comments on Europe and the Fairs

Conditions in the instrument industries in Europe are about the same as I reported last year except that the hourly wages have increased about 30 percent with a resultant increase of approximately 25 percent in the value of the annual production per man, and 25 percent in sales price.

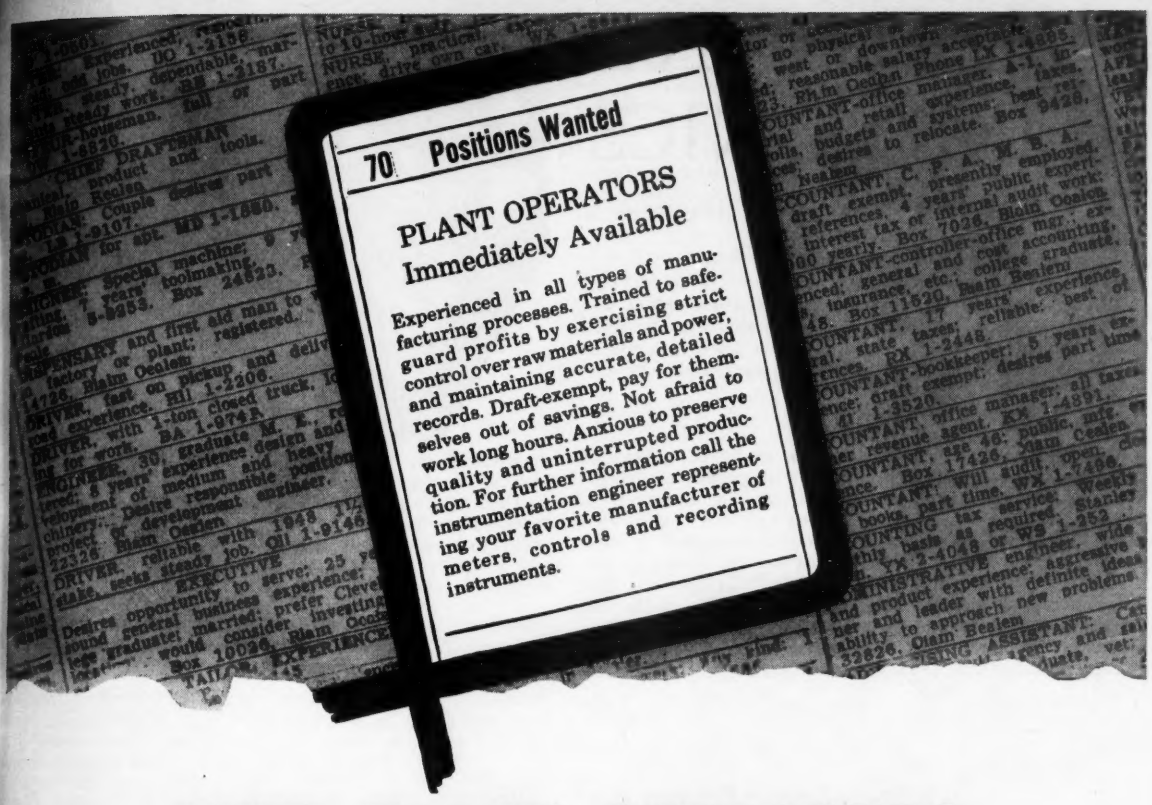
In the Paris Fair and the British Instrument Industries Fair, the number and size of the instrument exhibits decreased considerably. The chief reason is the recognition on the part of the instrument manufacturers that the large general fair is not as good a sales promotion medium as the trade exhibit. With the increase in specialization, all countries eventually will have instrument exhibits. Scientific instrument exhibits now are held in London, Paris, and Stockholm, and an exhibit of apparatus (including instruments) is held in Germany.

The huge size of European fairs and exhibits is probably due to the fact that the European and British manufacturer is more familiar with such display as a sales-promotion medium. The American manufacturer, on the other hand, uses trade-paper advertising more effectively.

From the instrument man's point of view the displays of instruments were not set up properly at the British Industries Fair, the Hanover Heavy Industries Fair, or the Paris Fair. At Hanover the instruments were distributed over ten halls. Somewhat the same condition existed at Paris and in the BIF, where the fair was divided into three parts, of which two were in London and one in Birmingham, three and a half hours by train from London. Instruments and devices for measurement, inspection, testing, and automatic control should have been brought together in the same hall. If this had been done, the instrument engineer attending the Fair would not have had to walk all over the grounds. This arrangement also would have reduced the number of curiosity-seekers, and thus there would have been less interference with those interested in instruments.

Continued on page 1092

See Editorial Page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* * * * *

Truly, modern, precision instrumentation is management at its best—devoted to the safeguarding of quality and uninterrupted production, and the preservation of profits through economical control of power, raw materials and goods in process.

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INSTRUMENT ELECTRONICS

By M. H. ARONSON, Managing Editor, *Instruments*

II. CIRCUIT ELEMENTS
Part 2. Inductance

Two of the three basic circuit elements—resistance and capacitance—have been discussed. Inductance is the third basic element of electric circuits. Inductance is a result of changes in the magnetic field which surrounds any current-carrying conductor.

Magnetic Field

Like the electric field between the plates of a charged capacitor, the magnetic field around a magnet or a current-carrying conductor cannot be seen. Unlike the electric field, however, the presence of the magnetic field can be indicated simply by bringing a compass near the magnet or conductor; the needle of the compass always indicates the direction of the magnetic field. Lines with arrows are used commonly to denote the field, as shown in Fig. 2-15. The lines are called *lines of magnetic flux*, or *flux lines*. The strength of a magnetic field is indicated by the number of lines of flux per unit area. The strength of the field around

Fig. 2-15. Magnetic fields. A, field produced by a magnet; B, field produced by direct current in a straight-wire conductor; C, field produced by direct current in a coil.

the current-carrying conductor depends on the current in the conductor.

When the conductor is fashioned into a coil, the magnetic lines of flux encircle each wire of the coil. Therefore, the flux lines combine in the center of the coil to produce a strong magnetic field, as shown in Fig. 2-15,C. In the space between any two adjacent turns, the lines of force are equal in strength and opposite in direction and, therefore, cancel each other. If many turns of wire are wound in the form of a coil, a strong magnetic field can be produced with only small current. A conductor wound in the shape of a coil is called an *inductor*, a *reactor*, or a *choke*.

Reluctance.—Magnetic lines of force encounter a certain amount of opposition, called *reluctance*, in all materials. If the reluctance of a material is low, the number of lines of magnetic flux in that material is large—that is, a strong magnetic field can be produced easily in the material. As iron has much less reluctance than air, the magnetic flux produced by current in a coil is increased greatly by the insertion of an iron core within the coil. The large number of lines of force inside the coil then travel through the iron, making the iron a magnet. A magnet of this type is called an electromagnet. When a soft-iron core is used, a stronger field is produced than if a steel core is used. This is because iron offers less opposition than steel to lines of flux. Therefore, soft iron is said to have lower reluctance, or greater *permeability*, because it carries magnetic lines of force more easily. As shown in Fig. 2-16, the high permeability of iron causes a magnetic field to be increased near the iron. Table IV lists the permeabilities of some common materials used in inductors. The permeability of a vacuum is 1; that of air is very close to 1.

Nonmagnetic metals, such as copper or brass, have lower permeability than air. Therefore, they decrease the magnetic field around a coil when used as a core in the coil.

Core saturation.—As current in a coil increases, the magnetic field, or flux density, around the coil increases also. However, when a magnetic core is used, a point is reached where an increase in current produces no further increase in flux density. This point is known as the core saturation point. Core saturation is used in constant-voltage transformers and in magnetic amplifiers, as will be explained later.

Instruments used by Sola Electric Co. in research on constant-voltage transformers.

TABLE IV.—PERMEABILITY OF SOME COMMON MATERIALS.

Substance	*Permeability (approx.)*
Vacuum or air	1
Cobalt (Co)	170
Nickel (Ni)	600
Pure iron (Fe)	6,000
Silicon steel (Si 4%)	10,000
Iron-cobalt alloy (Co 34%)	13,000
Permalloy (Ni 78.5%, Fe 21.5%)	80,000

Hysteresis.—Some magnetism remains in the core of an electromagnet after the magnetizing force (current through the coil) drops to zero. This *residual magnetism* causes the magnetic flux to lag behind the magnetizing force, or current. The lagging of the magnetic field behind the magnetic force which produces it is known as hysteresis. Like a spring which does not return to original size when the spring tension is released, hysteresis is a troublesome source of error in instruments, such as magnetic amplifiers, which depend on core saturation for operation.

Induced emf.

Whenever a conductor is moved in a magnetic field or, conversely, whenever a magnetic field moves past a

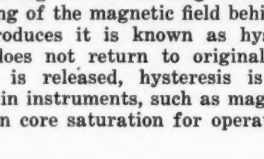


Fig. 2-16. Effect of the high permeability of soft iron on a magnetic field.

conductor, an emf. is induced in the conductor. This is the basic principle of operation of the electric generator. An emf. is induced whenever lines of magnetic flux cut across a conductor.

Consider a coil connected across an a-c. generator. The applied emf. causes alternating current, which causes a magnetic field. As the magnetic field expands and contracts about the coil, the lines of flux move away from, and then fall back into, the coil. The lines of flux cut across the conductors of the coil (and also across any other conductor near the coil). Therefore, emf's. are induced in the conductors by the lines of flux.

The emf. induced in the coil has a polarity *opposite* to that of the applied emf. As the induced emf. always opposes the applied emf., the induced emf. is called *counter emf.* This counter emf. opposes any variation of the current; when the current is increasing, the counter emf. opposes the growth of current; when the current is decreasing, the counter emf. opposes the decrease and keeps the

current flowing. Thus, inductance is analogous to the inertia of a mechanical mass. When you speed up an automobile, its inertia opposes the acceleration, just as the inductance opposes any current increase. When you take your foot off the accelerator, the inertia of the car carries it on, just as inductance keeps current flowing after the source of potential is removed. Inductance in a circuit tends to prevent *any change* in current through the circuit.

Unit of Inductance

In order to induce an emf., lines of flux must *cut* a conductor. Hence, counter emf. is induced only when current changes. Inductance is the property of a circuit element which determines the amount of counter emf. induced in the element by a given rate of change of current in the element.

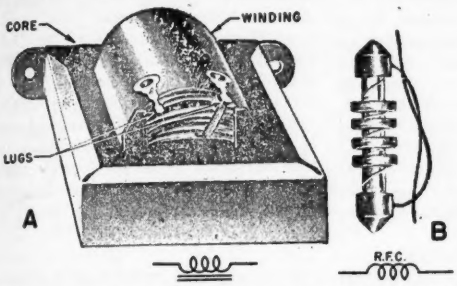


Fig. 2-17. Inductors and symbols. A, filter choke with iron core; B, radio-frequency choke with air core.

The emf. induced in the same circuit is called *self-inductance*, or *inductance* (*L*). That property of an electric circuit which determines how much emf. is induced in a neighboring circuit is called *mutual inductance* (*M*).

Inductance is expressed in *henrys* in honor of Joseph Henry, a discoverer of electromagnetic induction. A circuit element has an inductance of 1 henry if a uniform current *change* of 1 ampere per second through the element causes a counter emf. of 1 volt to be induced in the element. As a henry is a large unit of inductance, electronics men use smaller units, such as the millihenry (one one-thousandth of a henry) and the microhenry (one one-millionth of a henry).

The inductance of a component depends on the dimensions and shape of the component. It is independent of current (when the core is nonmagnetic), and can be defined in terms of the dimensions of the component and the magnetic permeability of the core. The equation for the inductance of a long, thin coil wound on an iron core is:

$$L = KuSN^2/10^8 l,$$

where K is 3.192 (when S is measured in square inches and l is measured in inches), u is the permeability of the magnetic circuit, S is the cross-sectional area of the core, N is the number of turns of wire wound on the core, and l is the length of the coil. This equation shows that inductance varies directly with the permeability of the core, directly with the cross-sectional area, directly with the square of the number of turns of wire, and inversely with the length of the coil.

The values of inductance used in electronic circuits vary greatly. Power-supply filters require an inductance of many henries. To obtain such high values of inductance, coils with many turns wound on iron cores are used (Fig. 2-17,A). Coils for high radio frequencies have air cores and an inductance of millihenrys and microhenrys (Fig. 2-17,B). Such coils are called radio-frequency chokes (R.F.C.).

Phase Relations in an Inductor

Fig. 2-18,A shows an a-c. generator connected to an inductor. E_0 and I_0 are meters for measuring the voltage (E) across the inductor and the current (I) through the inductor.

When the alternating voltage across the coil increases, the current tends to increase. The induced counter emf. opposes the increase. Therefore, the current increases in the coil *after* the impressed voltage increases. Likewise, when the current is decreasing, the induced counter emf. causes the current to fall off *later* than the impressed voltage. Thus, the current lags behind the voltage.

If a sinoidal voltage is impressed across a pure inductance, the current lags a quarter of a cycle, or 90 degrees, behind the voltage. This is shown in Fig. 2-18,B and C.

Note that the phase relations in an inductor are opposite to those in a capacitor. Whereas current leads voltage in a capacitor, voltage leads current in an inductor. This is why an inductor and a capacitor form a resonant circuit, as will be explained later.

Fig. 2-18,B shows also that the power (*W*) dissipated by a pure inductor is zero. The power at any instant is the product of the current and the voltage at that instant. Note that the power is positive for ¼ cycle and then negative on the next ¼ cycle. A period of positive power repre-

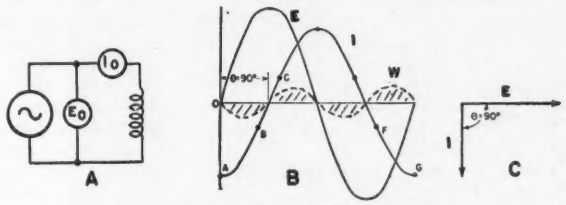


Fig. 2-18. Action of an inductor. A, circuit for measuring alternating current (I) through, and voltage (E) across an inductor; B, curves of E, I, and poker (W); C, phase relation between E and I.

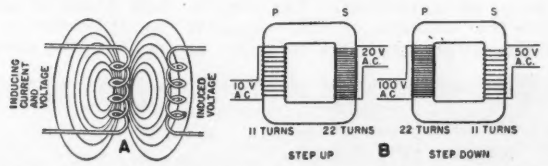


Fig. 2-19. Transformers. A, air core; B, iron core step-up and step-down.

sents the time when the inductor takes energy from the source in order to build up the magnetic field. A period of negative power represents the time when the magnetic field collapses and returns the energy to the source. Thus the average power consumed by the inductor is zero.

Inductive Reactance

The counter emf. in an inductor opposes the flow of alternating current. This opposition is known as inductive reactance (X_L) and is measured in ohms.

The magnitude of the counter emf. is proportional to the *rate* of change of the current through the coil. Therefore, the inductive reactance of a coil increases with the frequency of the current because a higher-frequency current changes more rapidly. The equation for inductive reactance in ohms is:

$$X_L = 2\pi FL = 6.2832\,FL,$$

where F is the frequency in cycles per second and L is the inductance in henrys. The reactance increases with frequency because (1) a higher frequency is equivalent to a greater rate of change of current, and (2) the counter emf. depends on the rate of change of current.

Like resistance, reactance is measured in ohms, and Ohm's law can be applied to inductors. The current flow through the inductor of Fig. 2-18,A can be determined by Ohm's law:

$$I = E/X_L.$$

Note that this equation is the same as Ohm's law for resistors and capacitors except that inductive reactance is used instead of resistance or capacitive reactance.

Mutual Inductance

When two coils are placed close enough to each other so that magnetic lines of force produced by one coil link the turns of the other, the coils are said to be inductively coupled. The inductively coupled coils are called a *transformer*. If an a-c. voltage is applied to one coil, an a-c. voltage is induced in the second coil (Fig. 2-19). This

Continued on page 1080

INSTRUMENTS ON THE MARCH

New Principles, Applications, Non-commercial Developments

R-f. Dielectric Standards

WASHINGTON, D. C.—To aid in determining the properties of dielectrics and their dependence on frequency, temperature, and humidity, the National Bureau of Standards has established radio-frequency standards for dielectric measurements, according to Technical Report 1529. For solid dielectric specimens, dielectric constant and power factor calibration services are now available in the frequency range from 10 kc. to approximately 600 Mc. Somewhat more limited calibration services also are offered for gases and liquids.

The NBS technique for evaluating dielectric properties employs a disk-shaped capacitor made from the material to be investigated. The complex dielectric constant of this capacitor is conveniently measured by bridge or resonance methods. Special micrometer electrode systems are used consisting essentially of two plates (of near optical flatness) which form a variable capacitor. One electrode is insulated by a quartz disk; the movable or grounded electrode is attached to a holder by metal bellows arranged so that there are no sliding contacts. The position of the movable electrode is accurately controlled by a micrometer, and the capacitance of the entire system is calibrated against an incremental precision capacitor. The structure supporting the movable electrode forms an effective shield for the electrode system.

The NBS micrometer electrode system is used in conjunction with conventional bridges or resonance indicating devices. The dielectric specimen is inserted between the electrodes, and the bridge is balanced or the circuit resonated. The specimen is then removed and the spacing between the electrodes is reduced until the bridge rebalances or the circuit re-resonates. The dielectric constant is determined from the capacitance corresponding to this reading on the micrometer dial and the capacitance corresponding to the micrometer dial when set to the known thickness of the specimen. This technique for determining the dielectric constant circumvents fringing errors. It is known as the susceptance variation method. It is valid with commercially-available bridges for frequencies up to approximately 300 Mc.

At frequencies above 500 kc., the power factor and dielectric constant are usually determined most accurately by a resonance method: The circuit including the electrode system and the

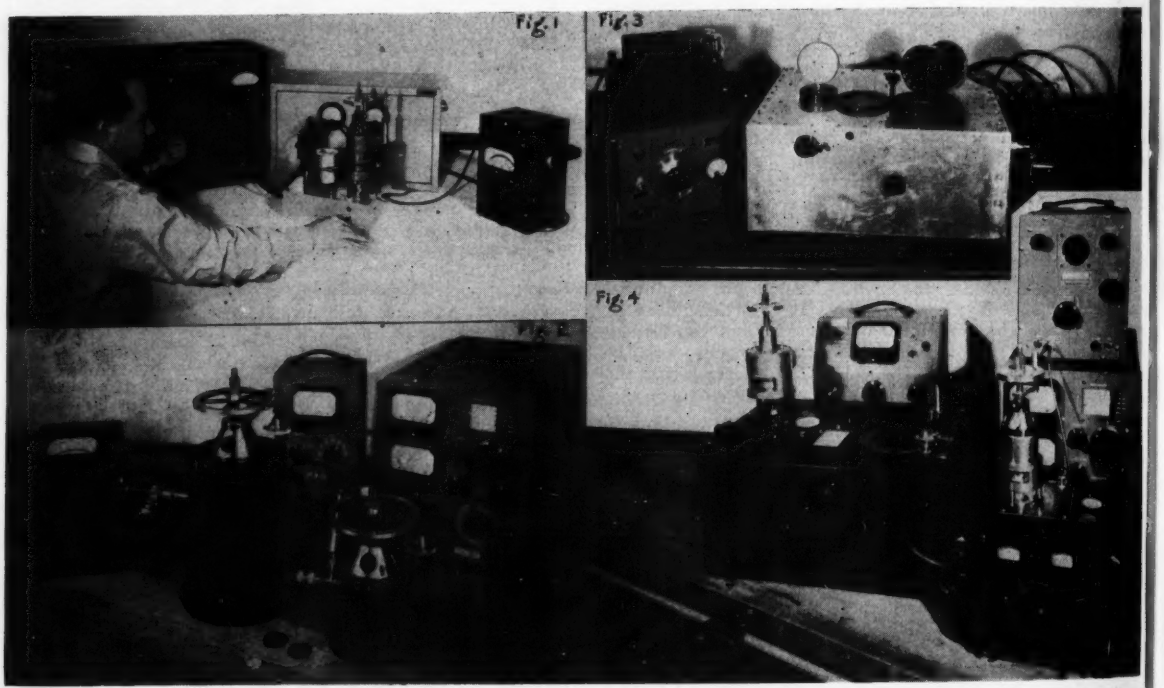


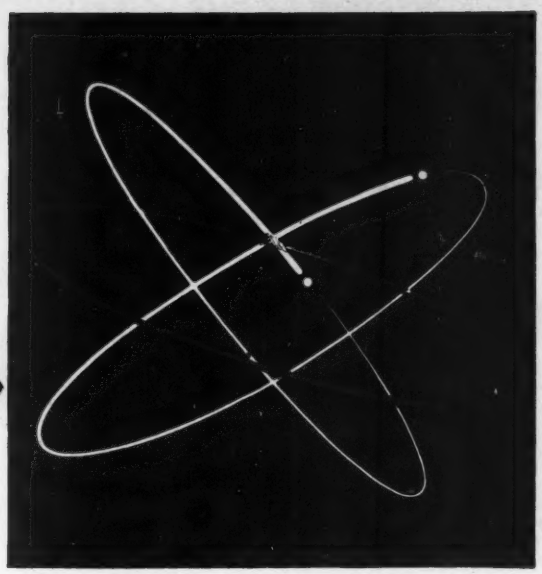
Fig. 1. NBS apparatus for measuring the dielectric constant and power factor of materials such as polystyrene or quartz. The measuring unit (center foreground) consists of a negative resistance circuit, which yields Q values of 100,000 at frequencies near 1 Mc. Sample material is inserted in an electrode system (above operator's hand) which serves as a variable capacitor, and a voltmeter (right) measures the voltage across this capacitor-electrode system. At left, h-f. generator; in center, d-c. power supply.

Fig. 3. Equipment used at the NBS for dielectric measurements under controlled conditions over a wide range of temperature and humidity. The measuring unit (center) is designed so that ten specimens may be conditioned simultaneously and measurements made individually on all specimens without opening the test chamber. This system is used up to 30 Mc. The auxiliary apparatus are the humidity and temperature controlling units.

Fig. 2. NBS resonant cavity apparatus for determining dielectric constant and power factor. The specimen, made into circular disks (center foreground), is inserted into the cavity to form part of the resonant circuit. The dielectric constant and power factor are determined from the micrometer readings and the voltages (voltmeters at left) across the specimen. At extreme right, signal generator. Cavity at left operates in range from 150 Mc. to 300 Mc.; smaller cavity in right foreground operates from 400 Mc. to 600 Mc.

Fig. 4. Equipment for measuring dielectric constant and power factor at the National Bureau of Standards. The NBS electrode systems are designed so that they may be conveniently plugged into most commercial bridges. In the foreground are two bridges of different frequency ranges with the electrode systems plugged into position. Typical disk specimens are on top of each bridge. Monitoring and frequency generating equipment in background.

first *all-electronic control*



of pressure

temperature

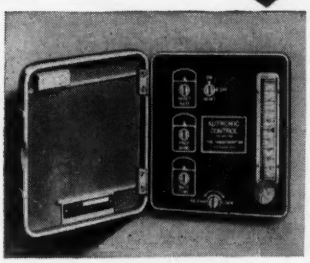
flow

and level ...

The new Swartwout Autronic Control System is the first miniature all-electronic control system for process and power instrumentation. Completely revolutionary in conception, it is the ultimate in centralized control no matter how stringent your requirements for accuracy, speed, reliability and compactness.

Because transmission of information throughout the Autronic Control System is by electrical means *only*, there is no transmission lag; control of final element is accurate, positive and *instantaneous*. Right from the primary measuring element to the final element there is no mechanical motion whatsoever . . . no slide wires to initiate control action . . . no booster mechanisms or other delicate equipment to overcome distance effects . . . no trouble caused by air leaks or frozen air lines.

Call in our engineering representative to explain how the Swartwout Autronic Control System can bring new accuracy and speed to *your* process instrumentation and control. Or write *today* for literature on the new Swartwout Autronic Control System.



Swartwout *Autronic* CONTROL SYSTEM

THE SWARTWOUT COMPANY • 18511 EUCLID AVENUE • CLEVELAND 12, OHIO

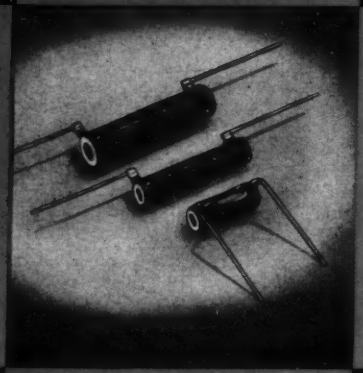
OHMITE
WIRE-WOUND RESISTORS

"DIVIDOHM" ADJUSTABLE TYPE

Vitreous-enameled type, with windings exposed along one side for contact with adjustable lugs. Used for final resistance adjustments; for securing odd values quickly; and as voltage dividers. In 10 to 200 watts; 1 to 100,000 ohms.

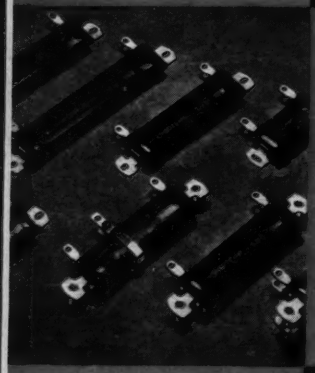
WIRE LEAD TYPE

These small vitreous-enameled resistors can be connected and supported by their own 1½" tinned copper terminal leads. All-welded construction makes possible higher resistance values. Size—5, 10, and 20 watts; resistance values—0.4 to 2,500 ohms.



LUG TYPE

This type is the most popular, having wide use in general applications. Vitreous-enameled coating. Connected by soldering or bolting leads to the lugs. Available in five standard core sizes — 25 to 200 watts; resistance values from 1 to 250,000 ohms. Special sizes and terminal arrangements also available.



THIN TYPE

Compact design gives these vitreous-enameled units a higher wattage rating per unit of space. Integral mounting brackets cannot rotate or loosen. Special studs allow stacking. Units are only ¼" thick, 1" wide, and 2" to 6½" long. Five sizes, from 30 to 75 watts; resistances—0.1 to 100,000 ohms.

"CORRIB" TYPE

Vitreous-enameled coating holds edge-wound, corrugated ribbon winding securely in place. For low resistance applications where high wattages must be dissipated. Many resistances available in a wide range of core sizes from 90 to 1,500 watts.

PRECISION TYPE

These ½- and 1-watt units, of 1% or closer tolerance, are used in test equipment, amplifiers, etc. Standard vitreous-enameled units, or pie-wound, non-inductive windings, in vacuum-impregnated or glass-sealed types. From 0.1 to 2,000,000 ohms.

NON-INDUCTIVE TYPE

For practically constant resistance and impedance in R.F. circuits, such as radio transmitters, diathermy apparatus, R.F. test equipment, dummy radio antennae. Vitreous enameled. Available in sizes from 50 to 160 watts, and in resistances from 5 to 5,000 ohms.

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FROM THE MOST COMPLETE LINE ON THE MARKET—

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specimen is resonated, and the voltage across the unknown is recorded. The specimen is then removed, the circuit re-resonated, and the voltage across the air capacitor is recorded. From these voltages and the known Q of the electrode system, the loss properties of the specimen are evaluated. Again, the dielectric constant is simply determined from the dial reading of the micrometer at the re-resonant point and the corresponding calibrated capacitance.

This resonance technique is used over a wide frequency range and is particularly applicable at frequencies above 100 Mc. At these frequencies the inductor becomes a single turn; therefore the method is to utilize a doubly reentrant resonant cavity (essentially a coaxial structure shorted at both ends with a variable gap in the center conductor) of either fixed or variable length. The test specimen occupies the gap between the reentrant posts. The frequency of operation of the fixed-length cavity is governed by the constants of the specimen inserted between the reentrant posts as well as by the geometry of the cavity. Consequently, the operating frequency cannot be specified in advance. The variable electrode, similar in structure to the movable electrode of the micrometer electrode system described previously, is also micrometer-controlled and is calibrated at the lower frequency in terms of the capacitance between the reentrant posts. This again permits measurements without appreciable corrections for lead inductance. The techniques used in the resonance method are equally applicable to reentrant-cavity measurements. Resonant cavities are advantageous because Q's of the order of 1000 to 3000 are readily obtainable, thus providing convenient voltage ratios.

Air-launched Automatic Weather Station

WASHINGTON, D. C.—A self-contained automatic weather station which transmits weather data by radio has been developed at the National Bureau of Standards for the Navy Bureau of Ships, according to Technical Report 1534. Named the "Grasshopper," the device can be parachuted from aircraft onto inaccessible territory. It automatically sets itself up and periodically makes and transmits weather observations. It can be used also as a radio marker-beacon.

The "Grasshopper" in upright position, ready for operation.

After the station has parachuted to earth, controlled explosive charges disengage the parachute, raise the station to an upright operating position, and erect a telescoping antenna. Weather-responsive devices then cause resistance changes, which switch a radio transmitter on and off at rates proportional to temperature, pressure, and humidity.

The radio transmitter consists of a crystal oscillator followed by a radio-frequency amplifier stage. A relay in the plate circuit of a relaxation oscillator turns the crystal oscillator on and off at a rate proportional to the value of a variable resistor, which is temporarily inserted by a clock mechanism into the relaxation-oscillator circuit. One variable resistor is sensitive to temperature, a second is sensitive to pressure, and a third is sensitive to humidity.

The clock, in addition to inserting the several weather-responsive resistors into the circuit in a predetermined sequence, connects two other resistors at appropriate intervals. These are a reference resistor and an identification resistor, both of constant value.

The developmental model of the weather station has an output of about 5 watts. Operating on a frequency of about 5 Mc., it has a land range of more than 100 miles. The dry batteries provide power for transmission of weather reports at 3-hour intervals for more than 15 days.

AGA Issues Instrument Book

NEW YORK CITY.—There has just been published the "Reference Book on Instruments for Electrolysis, Corrosion and Cathodic Protection Testing," prepared by the Subcommittee on Instrumentation of the American Gas Association. This is a letter-file-size binder composed of nine sections, marked by tabbed guides. The first section consists of 48 pages of text on characteristics and use of corrosion instruments and testing equipment. The other eight sections are made up of manufacturers' catalog sheets showing current models of instruments for electrolysis, corrosion and cathodic protection testing. Copies of this book are available from American Gas Association, 420 Lexington Avenue, New York 17, N. Y. The price is $1.50.

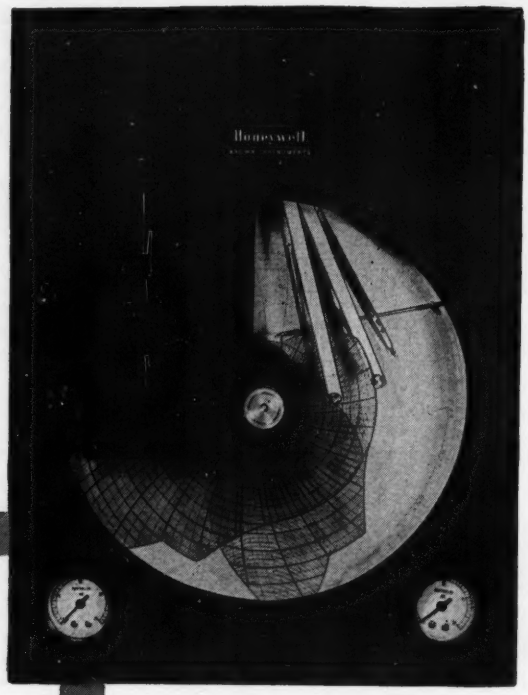
Press Brake Features Photoelectric Control of Ram Motion

CHICAGO, Ill.—What is believed to be the first press brake ever to utilize photoelectric control of the "ram" motion has been constructed by the Verson Allsteel Press Company of Chicago. Through use of a General Electric control system, the ram may be held completely level through its stroke, or may be operated at a preselected degree of tilt down to a thousandth of an inch.

The new press brake is hydraulically operated. The ram is actuated by two independent hydraulic cylinders supplied from separate matched pumps. A reversible booster hydraulic pump is used to transfer oil from one line to another to maintain position synchronization of the ends of the ram. The booster pump is driven by a motor supplied

Continued on page 1090

NOW PROGRAMMING AND CONTROL...IN



Check These

OUTSTANDING ADVANTAGES:

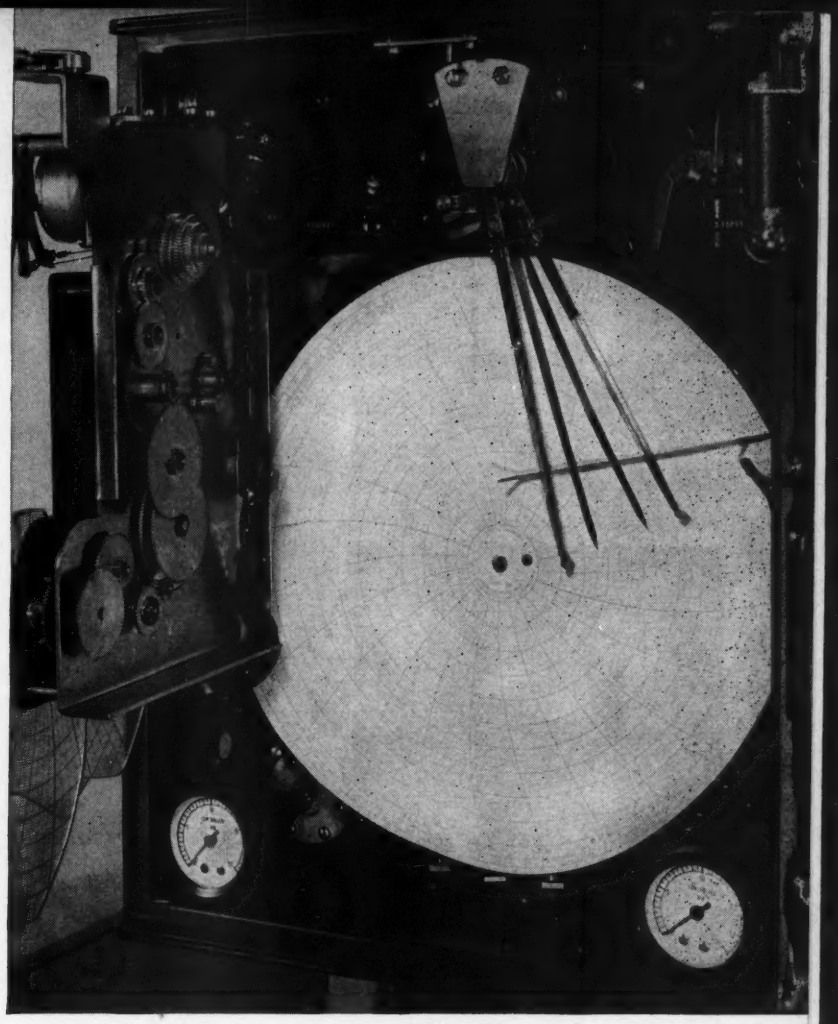
- √ *Requires less panel space.*
- √ *Controls one or two processes from one location.*
- √ *Affords electric or pneumatic control.*
- √ *Provides independent chart and cam drives.*
- √ *Permits wide range of cam speeds, ½ to 24 hours per revolution.*
- √ *Available with single pen, single cam; two pen, single cam; single pen, dual cam; two pen, dual cam.*
- √ *Visual or audible signals are optional . . . are operated by separate contacts which are adjustable throughout time range and may be used to interrupt cam travel or shut down process.*

DESIGNED to save space and reduce instrument investment, this new Brown thermometer permits measurement and control that heretofore required two control thermometers and two time-pattern transmitters.

Applicable where time versus temperature control is desired, it performs three separate functions from one case . . . for either one or two processes. Featuring integral cam programming, it (1) measures and records the temperature, (2) automatically positions the set point index, and (3) automatically controls the variable.

You get more compact control to save space, more accurate control to increase uniformity, more dependable control to raise operating efficiency. Check the list of outstanding advantages which appears at left.

...IN ONE CASE



THE NEW Brown integral cam program controller ... utilizing remote bulb thermal systems for temperature ranges from —125 to +1000° F. . . . is available with one or two pens and one or two cams as required.

The chart is visible at all times through the transparent cam and the hinged cam assembly can be swung out to change or mark the chart during operation . . . without any effect on the control or program.

The cam drive is independent of the chart drive, may be the same speed as the chart or a different speed. When two cams are used, they may be driven at the same speed or at different speeds. The variation of speeds plus the availability of dual or duplex electric and pneumatic control offer a flexibility which may solve the most difficult program control problems.

Write for a copy of Catalog No. 6020 . . . call in our local engineering representative for a discussion of your application.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

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Brown Instruments

H HONEYWELL

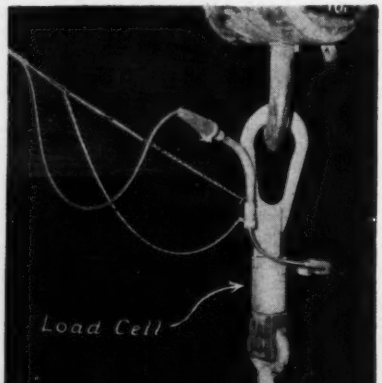
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

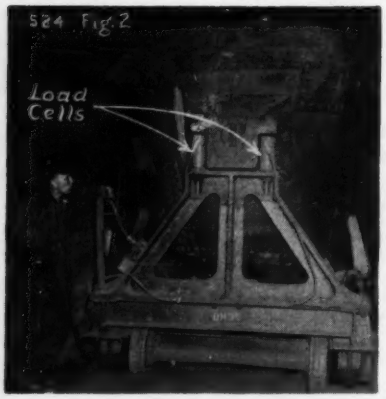
FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 1113

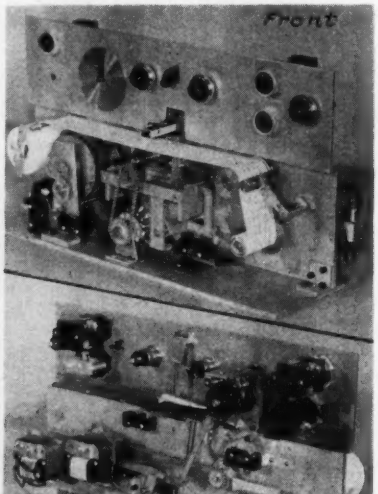
Electrical Weighing Systems

New industrial weighing systems are announced which comprise: (1) Baldwin-Lima-Hamilton Corp.'s load cells for converting tensions or compressions into voltage outputs; (2) installation components for adapting new system to hoists, cranes, platforms, continuous conveyors, mine cars, ladle trucks, etc.;



(3) suitable bridges and amplifiers; (4) maker's own remote indicators, printers, recorders or combination instruments. Functionally, new system is mechanoelectrical at primary force-measuring elements and electromechanical at final recording elements; and it utilizes purely electrical transmission; hence has advantage of being functionally non-electronic. (Electron tubes are used in amplifiers, but circuits are such that usual inevitable changes in tube characteristics do not affect over-all system accuracy; and checking and replacement of tubes is as easy as in radio receivers.) Among features: (1) spring take-up reels of brushless type for cables; (2) automatic temperature compensa-





tion resistors inside load cells; (3) automatic self-balancing bridge instruments; (4) weights can be printed on tapes, cards, ledger sheets, etc.; (5) range-change provision, especially desirable on large scales; (6) convenient zero adjustment; (7) maintenance problems said to be "practically nil" as compared to lever-system scales.—*Streeter-Amet Co.*, 4101 *Ravenswood Ave., Chicago* 13, *Ill.*

Mention No. 901 when filling out card.

Infrared Spectrometer

New "Model 12-C" Infrared Spectrometer features a densitometer attachment permitting accurate routine quantitative infrared reading to ± 0.025% in either transmittance or absorbance.—*The Perkin-Elmer Corp., Norwalk, Conn.*

Mention No. 902 when filling out card.

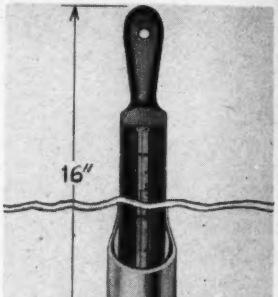
Air-operated Strip-chart Recorder-Controller

New automatic controller is said to combine advantages of pneumatic control and having a 120-foot-long 11-inch calibrated-width chart. Its self-balancing potentiometer has a 10-percent proportional band, a 150-percent proportional band and manual reset, or a 150-percent proportional band and automatic reset.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co.*, 4482 *Wayne Ave., Philadelphia, Pa.*

Mention No. 903 when filling out card.

Cupcase Thermometer

New "Model 8652 Cupcase Thermometer," meets all ASTM specifications, is narrow enough to fit into 2-in. gage pipes in oil storage tanks, is for use in oil industry where temperature affects volume of oil at time of sale. Cup capacity is 100 ml. as compared with smaller types of 20 to 60 ml. ca-

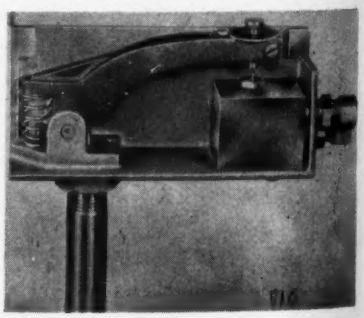


pacity. Hence slower response to temperature change as thermometer is raised from each reading depth and passes through varying temperatures at other levels, permitting accurate volumetric corrections for readings above or below sale price temperature of 60 F. Bulb is 0.625 in. from nearest wall of cup and almost centered to provide greatest possible lag. Cup has slanting top to prevent catching on obstructions.—*Tagliabue Instruments Div., Weston Electrical Instrument Corp.*, 614 *Frelinghuysen Ave., Newark* 5, *N. J.*

Mention No. 904 when filling out card.

Non-indicating Pneumatic Temperature Controller

New "Model HA" utilizes differential-expansion principle as does "Model H" but Micro-Switch is replaced by a pilot air valve that handles 15-psi.

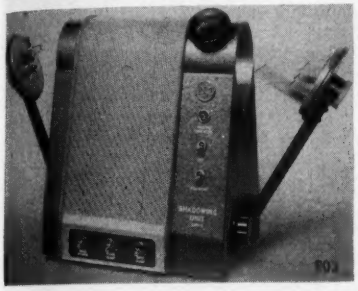


air pressure to operate any diaphragm motor or other power device. With standard tubes, "Model HA" provides a temperature range of sub zero to 1400 F.; up to 2000 F. with special tubes.—*Burling Instrument Co., 5 Vose Ave., South Orange, N. J.*

Mention No. 905 when filling out card.

Shadowing Unit for Electron Microscopes

New "Type EMV-6 Shadowcaster" is used to deposit a thin coating of tungsten, molybdenum, or other suitable material by evaporation on speci-

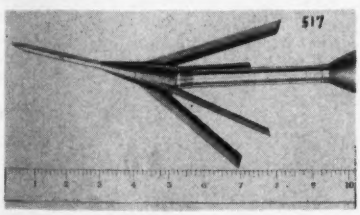


mens prepared for study in maker's electron microscope, providing necessary contrast to allow users to visualize third dimension of specimens. It speeds preparation by permitting processing as many as six glass slides at a time. —*RCA Engineering Products Dep't, Radio Corp. of America, Camden, N. J.*

Mention No. 906 when filling out card.

Pickups for Pitch & Yaw Angles and Pitot & Static Pressures

New "Ogive Pitch and Yaw Angle of Attack Pickup" operates at subsonic and supersonic speeds up to Mach 3. In operation, ogive and fin assembly swivel on a universal joint to face airstream at all times. Instru-

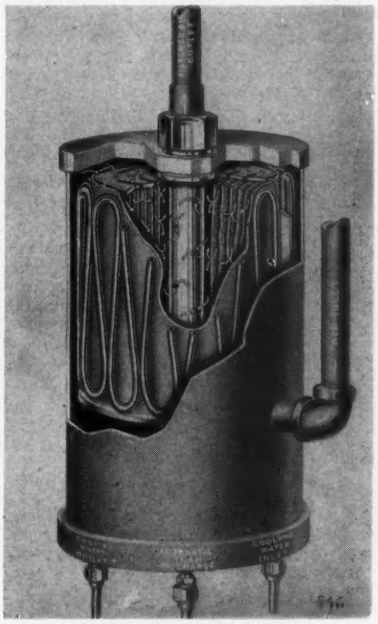


ment is available in two models: "Model 2519D" measures pitch and yaw angle of attack in ranges up to ±20 degrees with an accuracy of 0.2 deg.; ogive is 2.5 in. long. "Model 25112" is identical, with addition of a Pitot-static tube mounted on ogive; it faces airstream at zero angle of attack, ideally sampling static pressure. Ram pressure and static pressure are transmitted through universal joint with less than 1 percent error to pressure pickups in test vehicle; ogive with stinger is 5 in. long. Features of both models are high natural frequency, suitability for installation as leading portion of a spike antenna, and 0-5-volt d.c. electrical output.—*G. M. Giannini & Co., Pasadena 1, Calif.*

Mention No. 907 when filling out card.

Filter and Dehydrator for Instrument Air

New "Model B Condensifilter" removes water, oil, sludge and other foreign materials from compressed air. It combines a dehydrating device, a mechanical filter and a self-purging trap. Height 15 in.; diam. 9 in.; capacity 30 scfm. at 100 psi. Air is admitted through side, directed through condensing section where it is dehy-



drated, and then passed through mechanical filter. Total pressure drop is less than 2 psi. at 100 psi. Condensing unit, which removes water in both entrained and vapor states, is composed of a series of copper coils through which cold water flows. It lowers air temperature to within 2 deg. of cooling-water temperature; then, when air warms to atmospheric temperature again, a spread between temperature and dew point is effected. Filtering unit removes particles as small as 1 to 2 microns, is cleaned by immersing in a suitable solvent. For requirements greater than rated capacity of a single unit, "Condensifilters may be installed in parallel. (Same when uninterrupted service is desired.)—*Hankison Corp., 291 Renton Bldg., 1501 Beaver Ave., Pittsburgh 33, Pa.*

Mention No. 908 when filling out card.

Infrared Spectrophotometer

New "Model 21" Double-beam Infrared Spectrophotometer features a prism interchange assembly, allowing simple replacement of various prisms for infrared studies in different spectral regions. Prism, its table, Littrow mirror, wavelength and slit cams, and wavelength counter, are mounted on a separate assembly. For interchange, whole assembly is removed and alternate installed. Repositioning is determined by Littrow mirror bearing and cam shaft bearing.—*The Perkin-Elmer Corp., Norwalk, Conn.*

Mention No. 909 when filling out card.

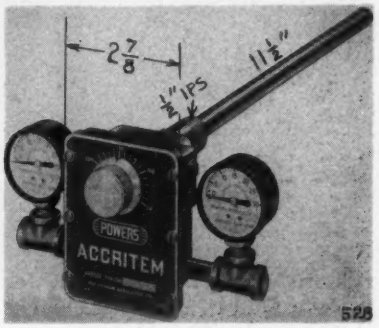
Air Pollution Instruments

Two new assemblies are announced of maker's "Thomas Autometer" for fully automatic analysis and recording of air pollution by SO_2— either an Integrating or Non-integrating assembly, complete with "Speedomax" recorder. (1) "Integrating Autometer" continuously records SO_2 concentration in ppm., records average concentration integrated over a half-hour period, automatically checks zero every 30 min. and marks off each cubic foot of air sampled. Non-integrating assembly provides only continuous record of SO_2 concentration.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 910 when filling out card.

Pneumatic or Hydraulic Temperature Controller

New "Accritem Temperature Regulator" is an expansion-stem automatic temperature controller with a fluid relay suitable for either compressed



air or water (at 15-psi. pressure) as the medium for operating maker's "Flowrite" or "Metaflow" diaphragm-motor valves. When water-operated, a drip-plug is supplied which discharges at atmospheric pressure. Temperature ranges: 50-250 F. and 150-350 F. Stem consists of outer copper tube and invar rod. Corrosion-resistant wells available.—*The Powers Regulator Co., 3501 Oakton St., Skokie, Illinois.*

Mention No. 911 when filling out card.

Remote Force Indicator

New improved "Tens-O-Trol" system measures tension, weight, or tractive loads remotely. Standard traction dynamometer with ball-bearing type synchro motor is connected by rubber-covered cable to repeater motor housed

in a metal cabinet. External 12-volt battery supplies current. Loads imposed on dynamometer transmitter are read on repeater station at distances up to 400 feet. Alterations have been made in cabinet size, appearance and dial layout.—*W. C. Dillon & Co.*, 1421 *S. Circle Ave., Forest Park, Ill.*

Mention No. 912 when filling out card.

Flexible Manometer

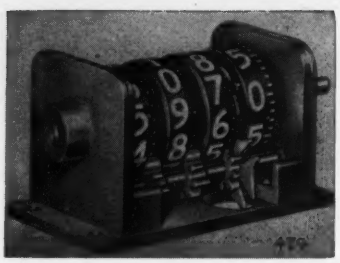
New flexible manometer for field use is made of durable vinyl-plastic; can

be rolled or twisted into shape. Plastic scale is firmly held between tubes and is adjustable.—*F. W. Dwyer Mfg. Co.*, 317 *S. Western Ave., Chicago* 12, *Ill.*

Mention No. 913 when filling out card.

High-speed Counter

New "Series 1370" counter is said to permit "higher speeds than ever before available in a mechanical counting device." It is rated at 1500 driveshaft rpm. (15,000 counts per minute



with a standard 10-digit unit wheel); withstands higher speeds for short operating periods.—*Veeder-Root Inc., Hartford* 2, *Conn.*

Mention No. 914 when filling out card.

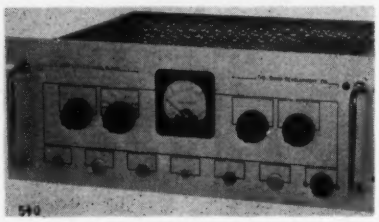
TV Transmitter Equipment

New "Model TA-124-E Image Orthicon Chain" comprises portable units: Pickup Head and Electronic View Finder; Image Orthicon Control and Monitor; Pickup Auxiliary; Mixer Amplifier; Low Voltage Supply; Synchronizing Generator; and Distribution Amplifier and Low Voltage Supply.—*Television Transmitter Div., Allen B. Du Mont Labs., Inc.*, 1000 *Main Ave., Clifton, N. J.*

Mention No. 915 when filling out card.

D-c. Amplifier

New "Model BL-962" direct-coupled amplifier, for use in standard 19-in rack and having a 7-in. high front panel, has voltage gain of approx.

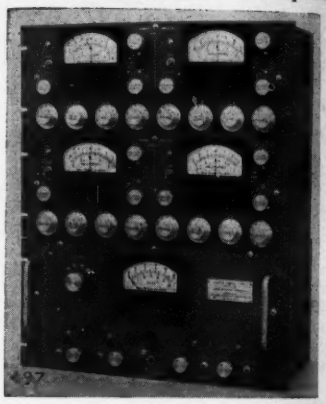


1000 times, sufficient to give 1 mm. deflection on chart of maker's oscillograph per millivolt input. Zero signal drift and effects of power-line fluctuation are minimized. When new amplifier is used with maker's penmotor, frequency response is essentially linear from d.c. to 100 cps.—*Instrument Div.* 33, *The Brush Development Co.*, 3405 *Perkins Ave., Cleveland* 14, *Ohio.*

Mention No. 917 when filling out card.

Laboratory Carrier Amplifier

New "Sierra" laboratory carrier amplifier is designed for making low-level measurements from tranducers of strain, displacement, pressure, temperature, velocity, acceleration, etc. To permit flexibility of use, equipment is housed in units which can be either mounted in standard 19-in. racks or bench-stacked as illustrated. One power



supply (lower cabinet) will energize one or two 2-channel bandpass amplifiers (upper cabinets.) Transducer inputs are brought to bridge circuits which are convertible for 1-, 2-, and 4-legged configurations for convenience in summing or difference-taking of transducer arrays through single amplifier channels. Bridges are of plug-in thermally-insulated design for quick interchangeability. Among other features: special network provides readings from 120-ohm strain gages with calibration directly in terms of steel stress. Static zero drift of oscillograph traces is compensated through an automatic zero-control circuit which permits unattended operation.—*Electronic Engineering Associates, Ltd.*, 1048 *Brittan Ave., San Carlos, Calif.*

Mention No. 918 when filling out card.

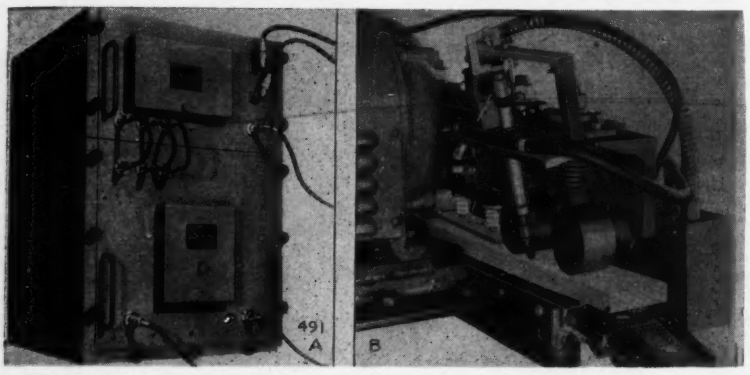
A-c. or D-c. Amplifier

New amplifier has input impedance of less than one ohm; frequency response uniform from d.c. to 5000 cps.; load impedance can be any value, 10,000 ohms

Automatic Inspector for Moisture Content

New "Laucks Sentry" continuously measures moisture content of products such as woods, veneers, etc.; and automatically marks or rejects all stock not complying with specification. Right-hand photo shows installation on a jointer machine in a furniture factory. Made by Instrument Div., Lauks Laboratories; marketed by *Lauks Sentry Products*, 4441 *Stuart Bldg., Seattle* 1, *Wash.*

Mention No. 916 when filling out card.

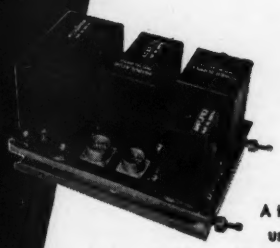


mechatronics*

We call it **mechatronics*** as a symbol for Servomechanisms', Inc., *technique* for the multiple and interchangeable use of standard, functionally packaged, servo components in varied electronic and electro-mechanical systems.

mechatronics fulfills the urgent need for

- Spatial Adaptability
- Instant Maintainability
- Training Simplicity
- Ease of Assembly



A typical Servomechanisms, Inc., assembly using mechatronic packaged functions.

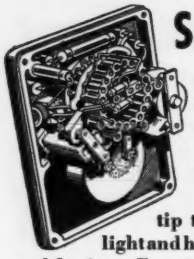
*Trademark

SERVOMECHANISMS* INC.

Ft. Lauderdale, Florida—El Segundo, Calif.

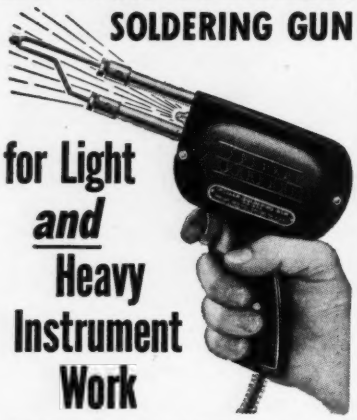
POST AND STEWART AVES., WESTBURY, N. Y.

Adjust Heat INSTANTLY for ALL TYPES of Soldering



Controlled dual heat—on in 5 seconds, off when you release trigger—lets you adjust tip temperature for light and heavy instrument soldering. Precision balance, longer reach and tip construction ideal for delicate jobs. Rating up to 250 watts speeds heavy work. Time-and-power savings pay for your Weller Gun in a few months.

250-Watt WELLER SOLDERING GUN for Light *and* Heavy Instrument Work



- **TRIGGER-SWITCH CONTROL**—Ideal for intermittent work. No need to unplug gun between jobs.
- **5-SECOND HEATING**—No waiting, no wasted current.
- **PRECISION BALANCE**—Simplifies delicate work.
- **SOLDERLITE**—Spotlights the work.
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See the 250-watt Weller Soldering Gun at your distributor, or write for bulletin direct.

SOLDERING GUIDE—Get your new copy of "Soldering Tips"—revised, up-to-date, fully illustrated 20-page booklet of practical soldering suggestions. Price 10c at your distributor, or order direct.

WELLER ELECTRIC CORP.
800 Packer Street, Easton, Pa.

or higher. Amplifier is said to be of a new type, in that it employs maker's "Model 303-A" electrically-operated electromagnetic capacitor. This new device consists of a Dural ribbon stretched in a strong magnetic field next to an insulated rigidly-fixed back-plate. Ribbon and back-plate constitute a capacitor. When a.c. or d.c. is passed through ribbon, capacitance value is altered. Resonant frequency is adjusted by adjusting tension. Ribbon movement, and hence capacitance change, is substantially uniform with applied voltage or current from 0 to 5000 cps. Sensitivity is adjusted by adjusting ribbon-to-plate spacing for any given tension. For most d-c. inputs (thermocouples, strain gages, etc.), resonance is adjusted to about 1600 cps.; for voice frequencies, about 4000 cps. Other models are available with shorter ribbons: up to 15,000 cps. Unit is unaffected by aircraft vibrations; is suitable also for medical and biological work with a few microamperes; lends itself to either positive or negative feedback applications.—*Phillips & Hiss Co.*, 1155 *N. McCadden Pl., Hollywood* 38, *Calif.*

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New "Adjustable Voltage Reference" is said to serve as a "secondary standard cell" operating from a-c. mains to provide a continuously variable d-c. supply over a wide range: 0.0001 to

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Mention No. 920 when filling out card.

Sweep Generator

New "Kilo-Sweep" is said to extend speed and accuracy of visual alignment techniques to the adjustment of high-fidelity and communications-type

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Noise and Field-intensity Meter

New slide-back circuit for "Model 58 U.H.F. Radio Noise and Field Strength Meter" is for accurate meas-

This New Controller Says "Hurry Up, Furnace!"

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This Control has something that's brand new in proportional, electric controllers. Called "rate action," this feature enables the Controller to act on the *speed* of swings in furnace load, as well as on their size and on the length of time they persist. Thus, if temperature changes gently, it is gently nudged back into line. But if it starts off vigorously—as when the furnace door is opened—P.A.T. 50 reacts vigorously. Then, when the change has been headed off, the Controller starts to back away. But "putting on the brakes" it brings temperature in line smoothly and rapidly.

Thus, "Rate Action" increases production because it reduces the length of time a furnace is off temperature.

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The News is in the Control Unit at bottom of panel shown at right. Earlier installations can be converted to P.A.T. 50 by replacing the Unit and making slight changes in the Controller.

For details, contact our nearest office, or write us at 4955 Stenton Avenue, Philadelphia 44, Pa.

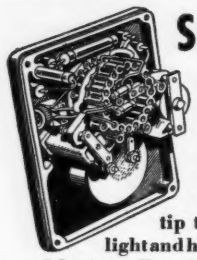
THESE furnaces and controllers are part of the slab-heating equipment with which The Timken Roller Bearing Company, Canton, O., conditions high-alloy steels for rolling. The Timken Company has used many earlier L&N Controllers. They find P.A.T. 50 is a further step forward, not only in guarding quality, but also in increasing production by shortening the off-temperature time.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND4-660(1)

Adjust Heat INSTANTLY for ALL TYPES of Soldering



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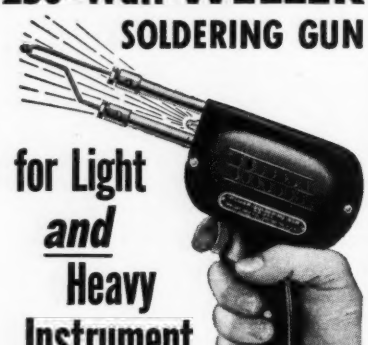

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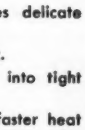

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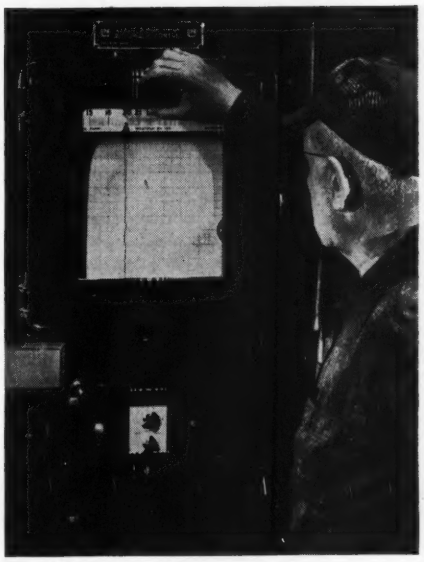

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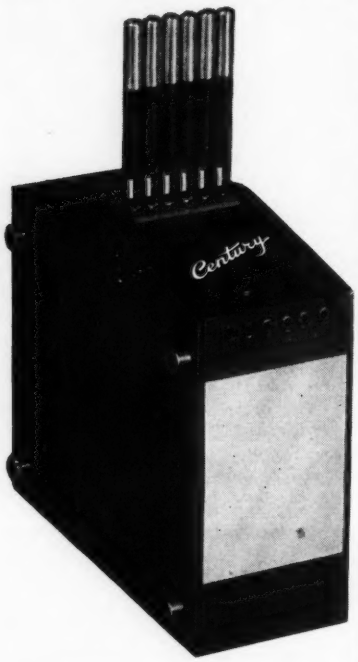
MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND4-660(1)

Century

RECORDING GALVANOMETERS



The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

Manufactured under Century Pat. 2439576, also licensed by Kannestine Laboratories Patent 2149442.

Century

CENTURY GEOPHYSICAL CORPORATION

1340 North Utica

Tulsa, Oklahoma

EXPORT OFFICE: 149 Broadway, N. Y. 1505 Race Street Philadelphia

World's Largest Manufacturer of Geophysical and Special Galvanometers

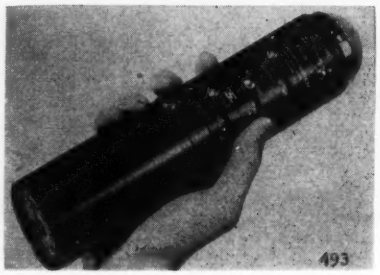
NEW INSTRUMENTS

urement of short pulses having slow repetition rate. Slide-back feature is available at additional cost. "Model 58's" already in use may be modified with kit or returned to company repair department for modification.—*Measurements Corp., Boonton, N. J.*

Mention No. 923 when filling out card.

Miniature Noise Meter

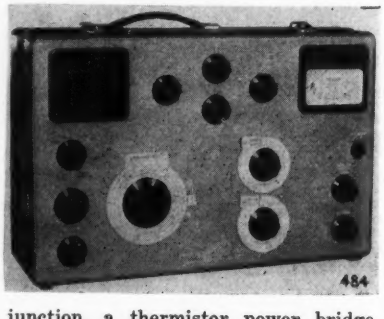
New "Type 410-B" sound level meter is a new model made possible by use of subminiature components and (patents-pending) miniaturization techniques. It meets all ASA specifications for sound level meters. Among features: greater low-frequency range, electric circuit improvements, and mechanical design refinements. Sound-level range is from 34 to 140 db above standard ASA reference level of 0.0002 dynes/cm.^{2}. Readily-obtained hearing-aid batteries have an operating life of about 50 hours. Optional accessories include carrying case, extension cables and vibration-measuring equipment.—*Hermon Hosmer Scott, Inc., 385 Putnam Ave., Cambridge 39, Mass.*



Mention No. 924 when filling out card.

R-f. Test Set

New "TF 890/2" is for testing radar receivers, transmitters, and antenna systems. Frequency coverage is 8500-9600 Mc. continuously variable; unmodulated continuous wave or FM constant amplitude; pulse or AM signal reception. Set is for use on 115 v. 60-cps. It comprises a 3-arm waveguide assembly radiating from a 120-deg. Y junction, a thermistor power bridge, a cavity wavemeter, a crystal mixer-detector, a frequency-swept kylstron oscillator, a sweep generator, a monitor receiver, a cathode-ray spectrum monitor, and a regulated power supply. These units are mounted in case shown in photo (approx. weight 50 lbs.). A separate directive feed unit and flexible connector are supplied for insertion in and connection to antenna waveguide of radar under test. New set permits measuring all important characteristics of radar under test.—*Marconi Instruments, Inc., 23 Beaver St., New York 4, N. Y.*



Mention No. 925 when filling out card.

Electrometer

New "Model 200 Vacuum Tube Electrometer" has accuracy of 1 percent at full-scale reading; within 5 percent at low-scale readings. Accuracy was achieved by re-calibration of scale to compensate for nonlinear characteristics of vacuum tubes.—*Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.*

Mention No. 926 when filling out card.

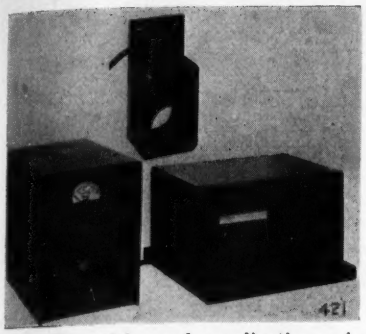
Television Bar Generator

New television cross-bar generator provides a linear pattern to adjust vertical linearity, height and centering as well as horizontal drive, width, peaking, linearity and centering. All tests possible when no station is on the air. Manufactured under license agreement with Western Electric by *Superior Instruments Co., 227 Fulton St., New York 7, N. Y.*

Mention No. 927 when filling out card.

Metal Detectors

New "Guardsman Series" metal detectors will inspect meat, bakery products, candy, plastics, paper, rubber, tobacco, textiles, explosives and many other non-metallic substances for minute tramp metal particles. Shown above is a small round-aperture type metal detection head; at right, a rectangular-type head which will inspect products passing through on a conveyor belt at rates of 10 to 1000 feet per minute. Control unit, shown at left, is the same

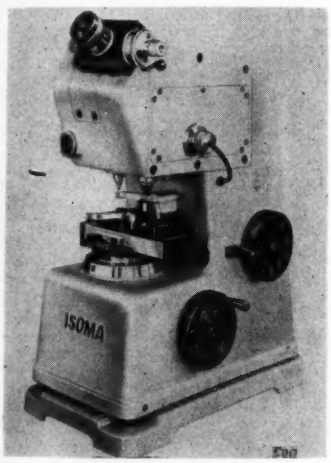


for all models and applications, is 8.25 x 6.75 x 10 in. deep, weighs 20 lbs. Installed detectors are practically immune from effects of building and conveyor vibration; are unaffected by normal humidity and temperature changes; may be scrubbed where required by purity standards. Designed and built by Eng'g Prod. Dep't, RCA Victor Div., RCA. Will be marketed by *Eriez Mfg. Co., Erie, Penna.*

Mention No. 928 when filling out card.

Hardness Tester

New "Isoma" hardness tester, for measuring Vickers values on small round and flat metal parts, foil, tinplate, glass, plastics, etc., has an automatic weight-selecting device for applying dead-weight loads from 50 to 1000



grams. Built-in optical measuring system permits measuring impressions to within 4 microinches. Standard equipment includes transformer for 110 or 220 volts, base plate, test block, spare bulbs and table of equivalent values. Special supports and clamps are available for holding thin material and extremely small parts.—*Cosa Corp.*, 405 *Lexington Ave., New York* 17, *N. Y.*

Mention No. 929 when filling out card.

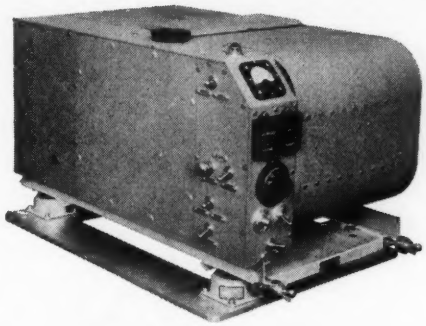
Dynamic Pressure-measuring System

New "Electro Linear Stabilized Pressuregraph" is an improved model of maker's "Pressuregraph." Features: Linear outline viewed directly on oscilloscope; drift and temperature stabilized; pressure range 0.5 to 10,000 psi.; frequency response from 0 to over

Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



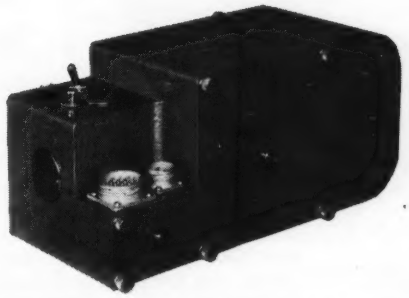
MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

- Size: 20" long, 12½" wide, 8⅞" high.
- Weight: 60 pounds.
- Number of Recording Channels: 6 to 50.
- Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.
- Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.
- Paper speeds continuously and instantly variable without changing gears or sprockets.
- Separate optical system for viewing before or during recording.
- Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.
- Data numbering at beginning of record.
- Footage indicator showing amount of paper remaining in magazine.
- Automatic record length control.
- Trace identification.
- Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

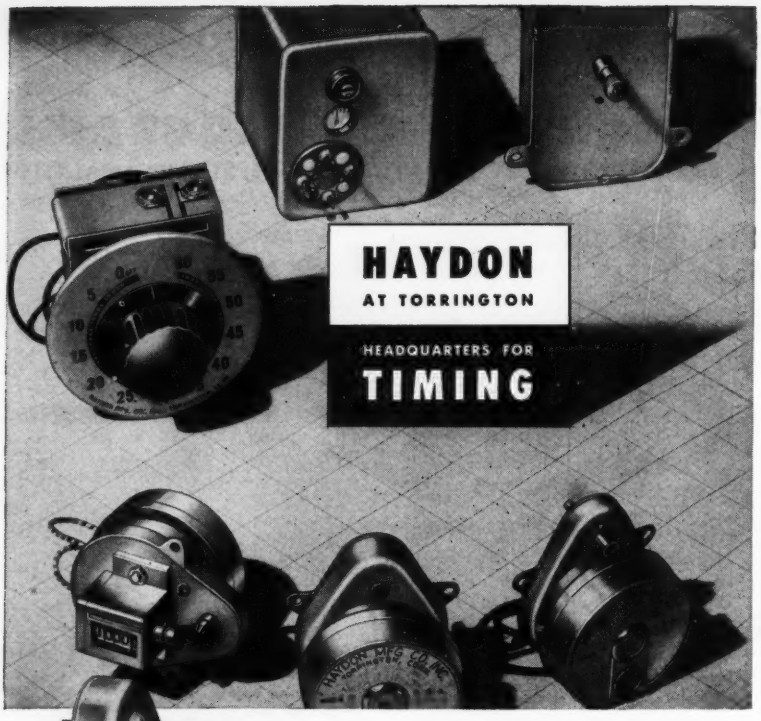
- Size: 5" x 5" x 11".
- Weight: 11 pounds.
- Cast Aluminum case.
- Paper speeds variable ½" to 12" per second.
- Detachable daylight loading magazine with a capacity of 3⅜" x 50' paper or film.
- 2 to 12 individual channels.
- Trace identification.
- Trace viewing.

For Complete Information Write 1340 North Utica

Century GEOPHYSICAL CORPORATION
TULSA, OKLAHOMA

1505 Race Street
Philadelphia, Pa.

EXPORT OFFICE:
149 Broadway, New York



SYNCHRONOUS TIMING MOTORS and TIMERS for

- *Industrial*
- *Military*
- *Commercial Uses*

400 Cycle Motor

HAYDON* research and engineering staffs constantly seek to develop new and build better products. One example is the HAYDON 400 cycle timing motor. This is an hysteresis type synchronous timing motor, for use as a separate motor or in many different types of timers. HAYDON personnel and plant are equipped to build motors and timers using D.C., 60 cycle or 400 cycle for military or civilian applications.

HAYDON manufactures a wide range of dependable timing motors notable for their small size; quiet operation; total enclosure; separate systems for controlled lubrication of rotor and gear train; ability to operate in any position. Standard speed range from 60 rpm to one revolution in 7 days. The HAYDON motor is the basic element for standard timing components and custom-engineered timers designed and manufactured by the company for volume applications.

DESIGN INFORMATION

HAYDON will gladly send you technical data on request.

*TRADEMARK REG. U. S. PAT. OFFICE

HAYDON Manufacturing Co., Inc.

Subsidiary of GENERAL TIME CORPORATION

2033 ELM STREET

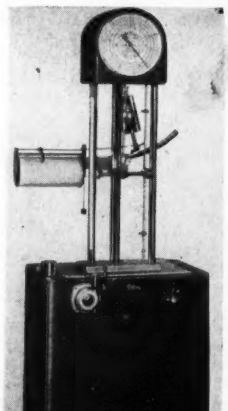
TORRINGTON **CONNECTICUT**

20,000 cps.; 200,000 separate pressure measurements per second; up to 200 ft. of pick-up cable can be used. Accuracy: Calibration repeats can be made to within 1 percent of full scale or rated pressure for any diaphragm. Static calibrations may be made with dead-weight tester.—*Electro Products Labs, 4501 N. Ravenswood Ave., Chicago 40, Ill.*

Mention No. 930 when filling out card.

Universal Testing Machines

New "Model $550" (motorized, illustrated) and "Model $390" (hand-operated, table) universal testing machines

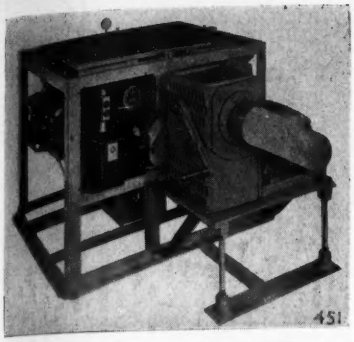


embody five major and numerous lesser improvements. New top range is 300 lbs.; new motor drive has stepless speed control from zero to 20 inches per minute; quadrant arm is now one continuous casting whose greater rigidity assures smoother stress-strain curves. —*W. C. Dillon & Co., Inc., 1421 S. Circle Ave., Forest Park, Illinois.*

Mention No. 931 when filling out card.

Vibration Tester

New vibration-test machine subjects aircraft accessories, etc., to circular motion in accordance with Navy and NEMA standards. Frequency range,

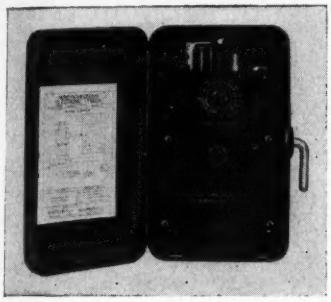


600-3300 cpm.; capacity, 125-lb. test load; amplitude radius, 0-0.0625 in.; mounting area of table, 24 x 36 in.; variable-speed drive from 220-v. 3-phase 60-cycle motor.—*Vibration Specialty Co.*, 1536 *Winter St., Philadelphia* 2, *Pa.*

Mention No. 932 when filling out card.

Welding Timer

New "Type 30CR3" automatic timer has adjustable timing range from 3 to 120 cycles with 2 percent accuracy;

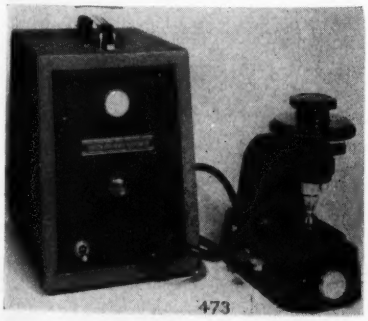


may be used with either 115-v. or 220-v. a-c. supply; provides "beat" or "non-beat" operation by selection of terminals. Load contacts are s-p.d-t. and are rated 10 amps. at 115 v. non-inductive. Dimensions 9.655 x 6.75 x 4.437 in.—*Photoswitch Inc.*, 77 *Broadway, Cambridge* 42, *Mass.*

Mention No. 933 when filling out card.

Electrical Micrometer

New "Carson-Dice Electronic Micrometer," for rapid measurements to a tolerance of 0.00002 in., permits "pressureless" measurement and eliminates "feel" as a source of error. Circuit is sufficiently sensitive to give a positive on-and-off indication with five micro-inches displacement at contact. Several models are available for use on



MODEL 500 BB

There's more to these

B-nobatrons

(DC POWER SUPPLYS)

than meets the eye!

MODEL 325 BB

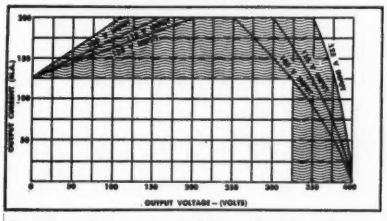
The Sorensen line of B-NOBATRONS is *conservatively rated*. The performance specified for each unit is available under *all line and load conditions* within the range of the instrument.

This leaves room for "plus values" that should not be overlooked! As shown in the graph at left, it is possible under many conditions to obtain current and voltage *considerably in excess* of the ratings. And you get similar premium performance from *all* B-NOBATRONS!

Further, the Sorensen name on any Isotronic* product is your assurance of careful construction, finest materials, dependable and economical operation. Write for full information.

* Isotronic is a trademarked word pertaining to the science of regulation and control of voltage, current, power, or frequency.

OUTPUT VS LOAD, MODEL 325BB



shaded section — area of "plus value" performance

DC POWER SUPPLY SPECIFICATIONS

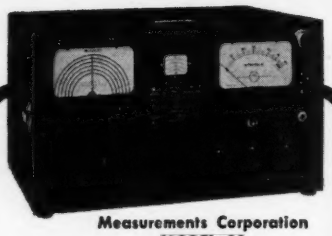
MODEL NO.	325BB	360BB	520BB	560BB	500BB	1000BB
Output voltage	0-325	175-360	200-500	0-500	0-500	200-1000
Output current	0-125 Ma	0-120 Ma	0-200 Ma	0-200 Ma	0-300 Ma	0-500 Ma
Output voltage, bias	0-150	.....	.....	0-150	0-150	.....
Output current, bias	0-5 Ma	.....	.....	0-5 Ma	0-5 Ma	.....
Ripple	10 mv	10 mv	10 mv	10 mv	10 mv	20 mv
Low AC voltage (center tapped, unregulated)	6.3 at 10 amp.	6.3 at 10 amp.	6.3 at 10 amp.	6.3 at 10 amp.	6.3 at 10 amp.	.....

Regulation accuracy: ±0.5% (±1% in 360BB and 520BB)
Input: 105-125 volts AC, 50-60 cycles, single phase.
Models 325BB, 560BB, 500BB and 1000BB are metered.
Units are normally self-contained. All can be provided with a front panel for rack mounting.

Specify SORENSEN

Sorensen & Company, Inc. • 375 Fairfield Ave., Stamford, Connecticut

For the best in regulated low voltage DC supplys, investigate Sorensen's line of NOBATRONS.



Measurements Corporation
MODEL 58

UHF RADIO NOISE & FIELD STRENGTH METER

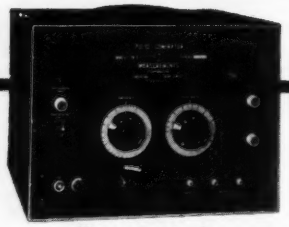
Frequency Range
15 Mc. to 150 Mc.

FREQUENCY ACCURACY: ±2%. Individually calibrated dial.

SENSITIVITY RANGE: 1 to 100,000 microvolts. Direct reading dial.

POWER SUPPLY: Built-in supply, 117 volts AC, 6 volts DC.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY



Measurements Corporation
MODEL 79-B

PULSE GENERATOR

REPETITION RATE: 60 to 100,000 pulses per second.

PULSE WIDTH: Continuously variable from 0.5 to 40 microseconds.

RISE TIME: Approx. 0.25 microseconds.

OUTPUT VOLTAGE: 150 volts (peak) positive.

POWER SUPPLY: 117 volts, 50/60 cycles.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

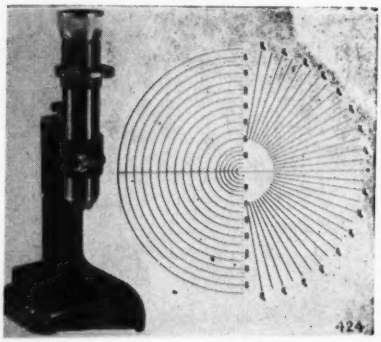
NEW INSTRUMENTS

compressible or non-compressible materials—conducting or non-conducting. All are portable, require no levelling and are unaffected by vibrations in temperature, line voltage or aging of electronic tubes.—*J. W. Dice Co., Englewood, N. J.*

Mention No. 934 when filling out card.

Toolroom Microscope

New "P. G. Cutter Grinder Microscope" is an English-made instrument for checking radii, forms and angles of engraving tools, small twist drills and

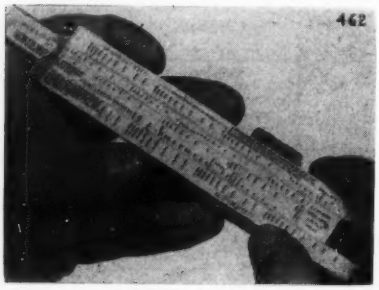


similar tools and components which carry an irregular shape at the end of a cylindrical shank. It consists of a 15× microscope with detachable reticle. Standard reticle (for inspecting engraving cutters) is illustrated; specials made to order. Eyepiece and objectives are interchangeable to vary total magnification.—*J. Arthur Deakin & Son*, 150-28 *Hillside Ave., Jamaica* 2, *N. Y.*

Mention No. 935 when filling out card.

Aerial-photography Slide-rule

New "Aerial Photo Rule" obviates need of tables and calculations; gives, by means of five scales, instant answers to problems such as: (1) Comparative size between objects on ground and in



a photograph; (2) area of land covered by one exposure at a given focal length, altitude and film size; (3) ground feet covered in flight per inch of photograph; (4) speed at which image moves under lens; (5) cycling time or exposure time in seconds required to cover image while plane flies at so many mph. at a given height and a given focal length. (6) image size; (7) planning flights. Available in 10-in. "Model 520" and 6-in. "Model 700."—*Pickett & Eckel, Inc., 5 S. Wabash Ave., Chicago* 3, *Ill.*

Mention No. 936 when filling out card.

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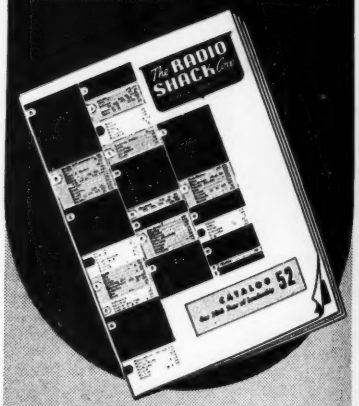

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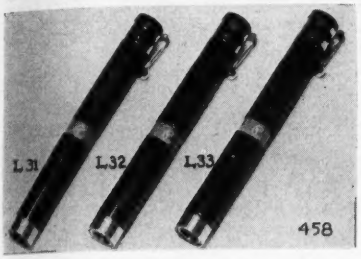
Radiation Dosimeters

New "Models L-31, L-32 and L-33" dosimeters have ranges of 5r, 10r and 50r respectively; are half-inch in diameter by 4 in. long; barrel of conduct-

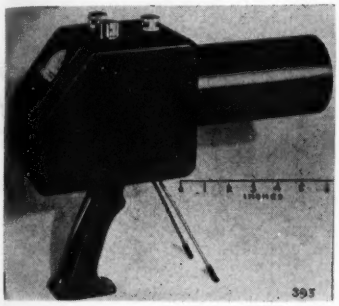


ing laminated Bakelite, hermetically sealed. Flexible plastic diaphragm for charging will not crack from use or aging. Instruments meet all standard specifications for their ranges. Charged on "L-21" charger. —*Landsverk Electrometer Co., (Aff. Technical Associates), 3730 San Fernando Road, Glendale 4, Calif.*

Mention No. 937 when filling out card.

Radiation Survey Meter

New "SU-1E" portable radiation survey meter employs new circuit with inverse feedback which permits ex-



tremely stable operation and a large reduction in time constant (now 1.5 seconds on all ranges). Calibration accuracy: ±10 percent of full scale. Ranges: 15, 150 and 1500 mr/hr.—*Tracerlab Inc., 130 High St., Boston 10, Mass.*

Mention No. 938 when filling out card.

Geiger-Mueller Counters for High-temperature Work

New "Phoenix" counters are so named, it is said, because of their infinite-life self-quenching mixture (ar-

YOUR SAFETY VALVES CAN BE

BOOBY TRAPS

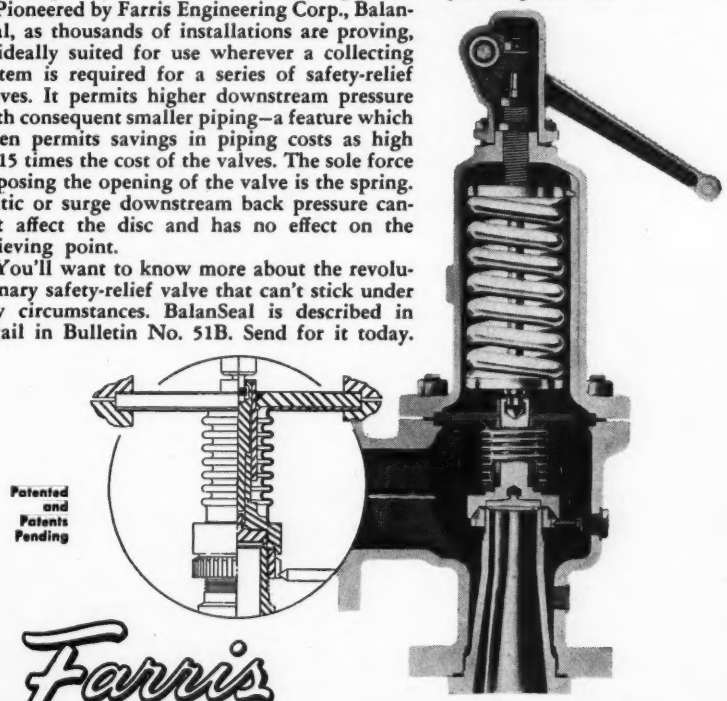
A safety valve that sticks is about as safe as a time bomb

Only BalanSeal© and FarriSeal© provide the positive protection at all times and under all operation conditions that makes them reliably safe.

Unique in design and principle, the BalanSeal Safety-Relief Valve has a protective bellows which is proportioned to eliminate any unbalanced downstream forces on the valve disc—which is perfectly balanced on its seat at the set pressure. Like its companion, the FarriSeal Valve, the guide, stem and spring are completely isolated from the lading fluid for perfect protection.

Pioneered by Farris Engineering Corp., BalanSeal, as thousands of installations are proving, is ideally suited for use wherever a collecting system is required for a series of safety-relief valves. It permits higher downstream pressure with consequent smaller piping—a feature which often permits savings in piping costs as high as 15 times the cost of the valves. The sole force opposing the opening of the valve is the spring. Static or surge downstream back pressure cannot affect the disc and has no effect on the relieving point.

You'll want to know more about the revolutionary safety-relief valve that can't stick under any circumstances. BalanSeal is described in detail in Bulletin No. 51B. Send for it today.



Farris

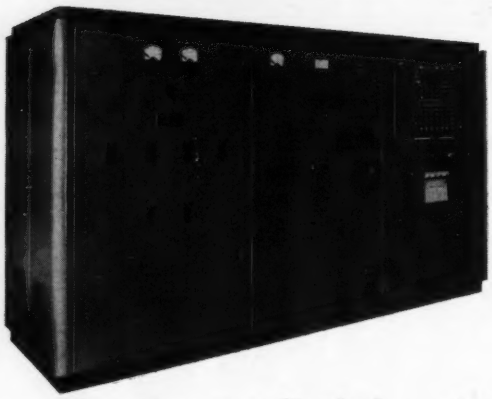
SAFETY and RELIEF VALVES

FARRIS ENGINEERING CORP.

536 Commercial Avenue Palisades Park, N. J.

7983

STANDARD CONTROL AND TEST PANELS



This is one of the many control panels we built for the intricate operation of the Supersonic Wind Tunnel for the Naval Ordnance Laboratory, White Oak, Md.

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Inquiries Invited

NEW INSTRUMENTS

gon, xenon, oxygen and nitrogen) which can be operated in regions of high temperature (unaffected by 142 C.) Units are cooled by water flowing through copper tubing.—*Radiation Counter Laboratories, Inc.*, 1844 *W. 21st St., Chicago 8, Ill.*

Mention No. 939 when filling out card.

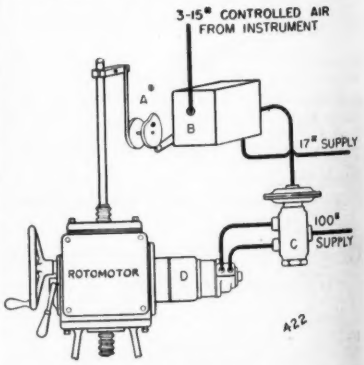
Demonstration Instruments for Nuclear Processes

New "DU-1A" and "DU-2A" are said to be inexpensive light-weight instruments to be used in demonstrating nuclear radiation processes. They can be used in detection of cosmic rays, alpha, beta and gamma particles, inverse square law of a point source, properties of absorbers in presence of various types of nuclear radiation, properties of Geiger-Mueller tubes and statistical nature of nuclear radiation and its indication on a ratemeter. In addition, both instruments can be used as inexpensive laboratory monitors, detectors of lost radioactive samples and with suitable calibration as survey meters. They may be extended to alpha detection by use of alpha scintillation tubes.—*Nuclear Research Corp.*, 2707 *Federal St., Philadelphia 46, Pa.*

Mention No. 940 when filling out card.

Power Positioner for Catalyst Slide Valves

New design of maker's "Rotomotor" is for operation of catalyst slide valves on throttling control services. "Rotomotor" is a completely pneumatic gear driven operator for positive positioning of large valves. Operating from normal plant air supply, it is said to eliminate not only original capital expenditure of hydraulic systems but also maintenance and safety problems involved. It is basically a self-locking mechanism. A continuously-connected handwheel and declutching lever also provide for manual operation if desired. Repositioning is accomplished by means of a tape type positioning device which permits long travels with



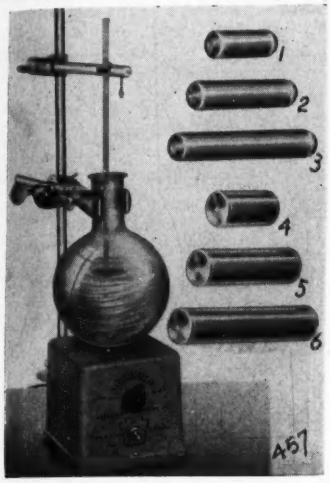
Positioning device B determines actual valve stem position by means of tape and cam connection A and desired stem position by air signal from control instrument. Corrected output air pressure from B then is fed to auxiliary pilot C which ports main air supply to pneumatic motor D, driving gear box clockwise or counterclockwise repositioning stem and completing pneumatic control loop.

accuracies of valve stem positioning to within 1/500th part of total valve stroke. Units can be mounted in valve manufacturers' factory and shipped to user ready for installation.—*Conoflow Corp.*, 2100 *Arch St., Philadelphia* 3, *Penna.*

Mention No. 941 when filling out card.

Magnetic Stirrer

New model of "Magne-Stir" features speed regulation. Teflon-covered stir-

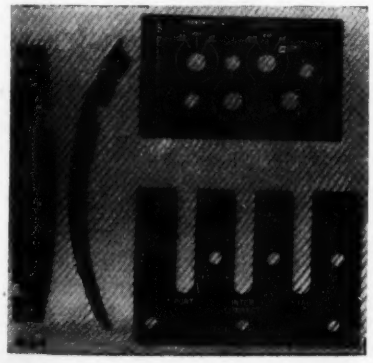


ring bars available in three sizes; also Pyrex-glass-covered stirring bars.—*Laboratory Industries, Inc.*, 4710 *W. North Ave., Chicago* 39, *Ill.*

Mention No. 942 when filling out card.

Edge-lighted Instrument Panels

New "Sierracin 5005" edge-lighting instrument panels have black backgrounds with white markings for daylight visibility. At night, markings glow red by means of small red lights placed in panel: light is carried



throughout transparent inner core of panel and escapes only through translucent letters and figures. Lights are properly located in each panel for even lighting; light bulbs are replaceable from front of panel. Screw-in light sockets are normally used to hold edge-lighted panel on instrument board. New panels are said to possess many features not covered by Specification AN-P-89. A deviation from AN-P-89 was

SANBORN

1, 2 and 4 channel

RECORDING SYSTEMS

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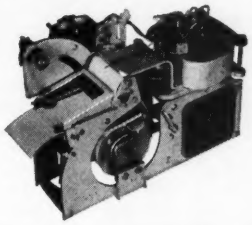
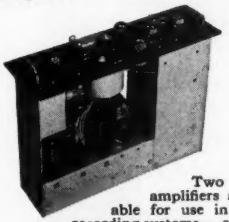
RECTANGULAR COORDINATES

PERMANENT RECORDS

RECORDERS AND AMPLIFIERS AVAILABLE SEPARATELY

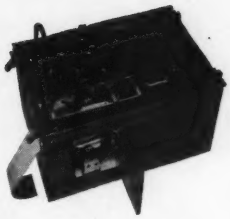


In all Sanborn recorders, tracings are produced by a heated writing stylus in contact with heat sensitive, plastic-coated paper. The paper is pulled over a sharp edge in the paper drive mechanism, and the stylus wipes along this edge as it swings; thus producing records in true rectangular coordinates. The writing arm is driven by a D'Arsonval moving coil galvanometer with extremely high torque movement (200,000 dyne cm/cm deflection). Standard paper speed for the Model 51-600 recorder assembly, shown above, is 25 mm/sec. Slower speeds are available. Paper width 6 cm with 5 cm recording area. The assembly shown above is used in Models 128 and 141 (described above right) and provides the basic principles and methods on which recorders for the 2- and 4-channel systems are designed.



Two types of amplifiers are available for use in Sanborn recording systems — a DC General Purpose Amplifier, and a Strain Gage amplifier (shown above). The amplifiers used in the 2- and 4-channel systems are generally identical with those in the 1-channel system, which are available, as are also all the recorders, for separate application.

1 CHANNEL RECORDING SYSTEMS



Model 128 comprises a DC General Purpose Amplifier in combination with the Recorder Assembly shown below left, to which is added panel, transformer, and controls. Both instruments are contained in a single hardwood carrying case. The complete system is a vacuum tube recording voltmeter capable of reproducing in rectangular coordinates any electrical phenomena from the order of a few millivolts to more than 200 volts. When a Strain Gage Amplifier is specified, the system becomes Model 141. Amplifiers are readily interchangeable. When a built-in timer is included for either, the Model numbers become 128T or 141T.

2 CHANNEL RECORDING SYSTEMS

The two channels of **Model 60** operate independently of each other, but record simultaneously. Ten paper speeds are standard equipment, in pairs of: 5 and 0.5, 10 and 1, 25 and 2.5, 50 and 5, 100 and 10 mm/sec. Ready interchangeability of amplifiers (DC and Strain Gage) and preamplifiers (DC and AC) makes possible the availability of a variety of input circuits. Timing and coding are built-in features. Each channel has a 5 cm recording width.

4 CHANNEL RECORDING SYSTEMS

Model 67 provides for the direct, simultaneous registration of up to four phenomena on one record, using the same principles and methods as the two systems described above. In addition, there is a selection of eight paper speeds: 50, 25, 10, 5, 2.5, 1.0, 0.5, and 0.25 mm/sec., and provision for the use of 4-, 2-, or 1-channel recording Permapaper. As in Model 60, above, amplifiers and preamplifiers are readily interchangeable.

For complete descriptions, illustrations, tables of constants, and prices, write for catalog.

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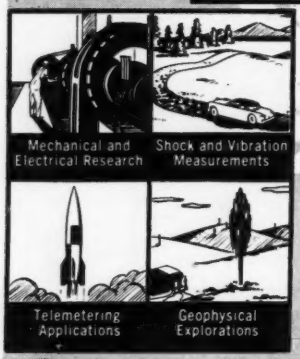

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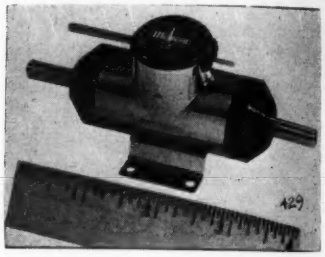
NEW INSTRUMENTS

granted to cover "Sierracin" non-crazing thermosetting plastic in lieu of the acrylics from which all other panels are fabricated, because (1) there is no possibility of crazing and resulting loss of light transmission and panel failure; (2) alcohol, lacquer thinner, methyl ethyl Keytone, standard commercial cleaners, aviation gasoline, Skydrol, etc., may be used without harm to clean "Sierracin" panels if they become soiled with grease or dirt—said to be "unique feature."—*Sierra Products Co.*, 1632 *E. Compton Blvd., Compton, Calif.*

Mention No. 943 when filling out card.

Variable-speed Drive

New "Type 4C" miniature variable-ratio speed changer has push-rod ratio control means, whereby a wide variety

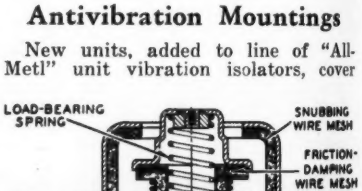


of control techniques is possible. Same size and construction as maker's "Type 4A" which has thumb-screw speed adjustment. Ratings up to 72 oz.-in. torque, 0.025 hp., 20,000 rpm.; ratio is infinitely variable from 1/6 to 6.—*Metron Instrument Co.*, 432 *Lincoln St., Denver 9, Colo.*

Mention No. 944 when filling out card.

Antivibration Mountings

New units, added to line of "All-Metl" unit vibration isolators, cover

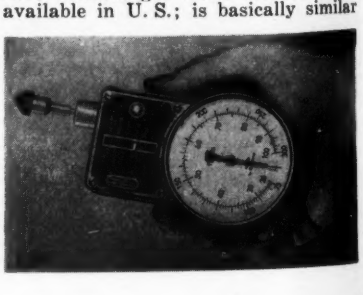


new load ranges of 8 to 16 lbs., 14 to 25 lbs., and 22 to 35 lbs.; meet shock requirements of Specification AN-E-19 for equipment sizes listed in JAN-C-172A.—*The Barry Corp.*, 820 *Pleasant St., Watertown 72, Mass.*

Mention No. 945 when filling out card.

Hand Tachometer

New model of "Dr. Horn" German-made centrifugal hand tachometer is available in U. S.; is basically similar

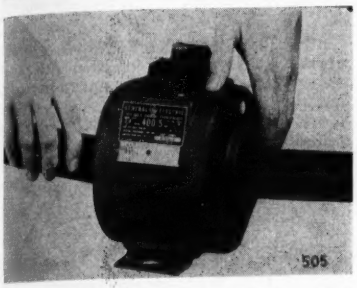


to model whose supply had been cut off. Six ranges cover 25 to 30,000 rpm.; overspeed protection is incorporated.—*James C. Biddle Co.*, 1316 *Arch St., Philadelphia 7, Pa.*

Mention No. 946 when filling out card.

Indoor-outdoor Current Transformer

New "Type JKP-O," 600-volt window-type indoor-outdoor current transformer is first of an entirely new line



supplementing indoor butyl-molded units described in complete detail in June 1949 *Instruments*, page 500.—*Meter and Instrument Dep't, General Electric Co., 40 Federal St., West Lynn 3, Mass.*

Mention No. 947 when filling out card.

Ceramic Capacitors

New miniature feed-thru ceramic capacitors "Types FT-20" and "FT-25" are 0.135 in. maximum diameter and rated at 500 volts, d.c. (working), 1,000 volts, d.c. (flash test). "Type FT-20" is available from 25 to 1,000 uuf; "Type FT-25" from 50 to 3,000 uuf.—*Centralab Div., Globe-Union, Inc., 900 E. Keefe Ave., Milwaukee, Wis.*

Mention No. 948 when filling out card.

Basic Chassis for Plug-in Construction

New Basic Chassis mounts component and circuitry for widely-varied applications; eliminates conventional

methods in which all wiring is boxed in; permits maximum accessibility to all components, wiring and assembly using high-speed production methods, and easy servicing of completed equipment.—*Alden Products Co., 117 No. Main St., Brockton, Mass.*

Mention No. 949 when filling out card.

CRO Time Markers

Three new models of maker's "Labmarker" are announced: "Model 1-U" differs from previous "1-U" in that it gives shorter pulses of less amplitude, is designed for scopes with Z-axis amplifier; pulse duration approx. one-

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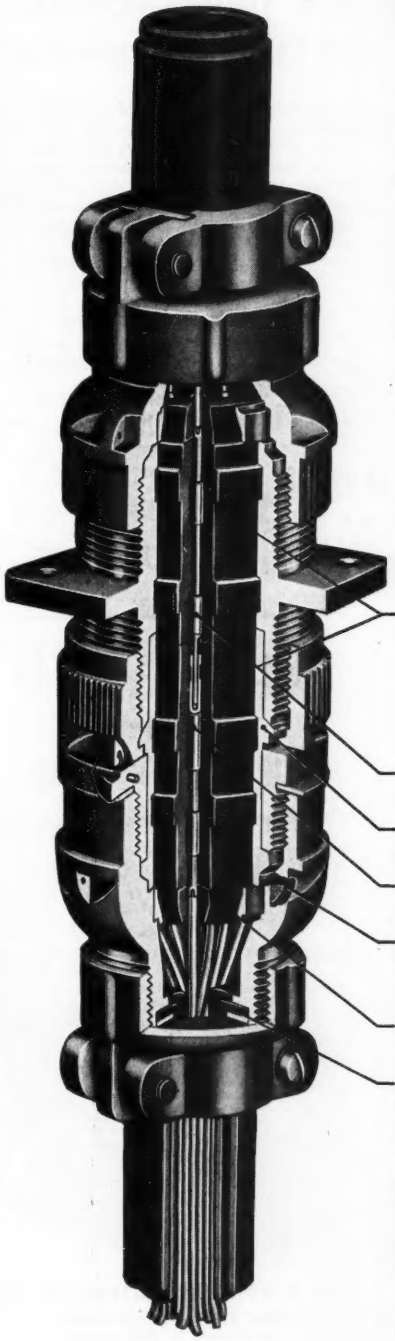

Here's another example of the meticulous care Cannon Electric uses in building connectors for highly specialized, tough jobs. This AN-"M" type connector is moisture-proof, vibration-proof and pressurized. Radio shielding is provided and every threaded part is drilled for safety wiring.

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Machined ball-in-cone joints provide radio shielding and improve vibration resistance.

Socket contacts machined from solid copper alloy with new Cannon design, silver-plated.

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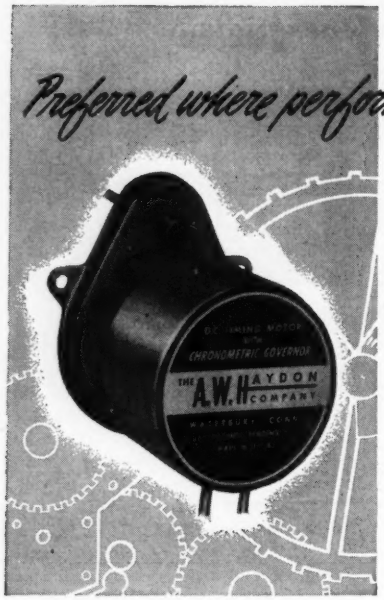

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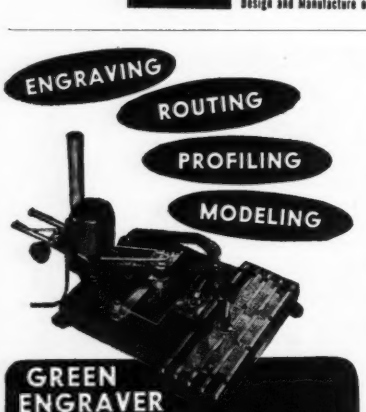

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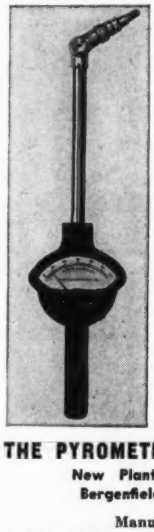

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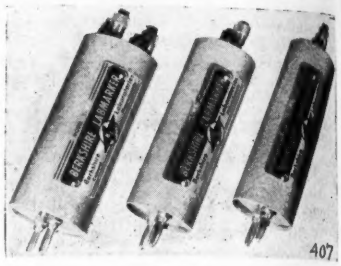


tenth cycle; both positive and negative pulses provided, 180 degrees apart if both outputs are used simultaneously. "Model 1-N1" is electrically similar to "1-U1" except that only negative pulses are provided. "Model 1-P1" gives only positive pulses.—*Berkshire Laboratories, 550 Lexington Rd., Concord, Mass.*

Mention No. 950 when filling out card.

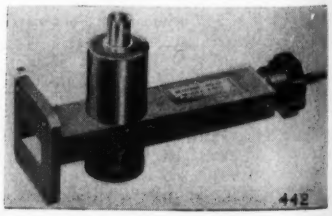
1.2-kw. Rectifiers

New "Style RA, Types N 150 VP and N 150 VQ" selenium rectifiers, designed especially for electroplating and electrochemical industries, have full-wave circuit with voltage continuously adjustable from 0 to 8 volts d.c. at 150 amps. or 0 to 16 v. at 75 amps. Breaker is calibrated magnetic (not thermal) type, giving full protection at all voltage settings. Cabinet is 25 in. high; has hinged top cover for easy access; is arranged for wall, shelf or floor mounting.—*Electronic Rectifier Co., Inc., Rochester 2, N. Y.*

Mention No. 951 when filling out card.

Waveguide Detector Mounts

New "485" detector mounts are designed to facilitate measurements of power at any frequency between 2600 and 18000 Mc. in conjunction with maker's "430A" power meter and a Sperry 821 barretter; may also be em-



ployed to measure relative level or detect r-f. energy using a Type 1N21 silicon crystal.—*Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.*

Mention No. 952 when filling out card.

Timing Motor

New 400-cycle timing motor is a hysteresis-type synchronous timing motor designed for timing applications in 400-cycle equipment.—*Haydon Mfg. Co., Inc., Elm St., Torrington, Conn.*

Mention No. 953 when filling out card.

Oscillator Triode

New "Type 6026" flexible-lead subminiature tube is a high-efficiency oscillator triode designed for transmitting

service at 400 Mc. in radiosonde and similar applications. In such service, it can deliver a useful power output of 1.25 watt.—*Tube Dep't, Radio Corporation of America, Harrison, N. J.*

Mention No. 954 when filling out card.

Tandem-type Connector

New "CS" tandem-type connector developed primarily for electric analog computers, is also adaptable on a-c. network analyzers. Single ¼-in-diam. silver-plated brass contact insures a large contact area within socket. Receptacle has two socket contacts in tandem, insulated from each other. Shells are aluminum alloy with phenolic insulators; accommodates a #12 B and S wire, minimum flashover of 2300 v., maximum 35 amps.—*Cannon Electric Co., 3209 Humboldt Street, Los Angeles 31, Calif.*

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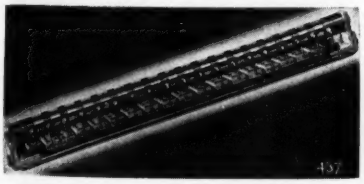
Delay Line

New "Type 1477-A" delay line has eighteen taps for selection of delay intervals from 0.05 to 0.9 microseconds. Characteristic impedance, 680 ohms;

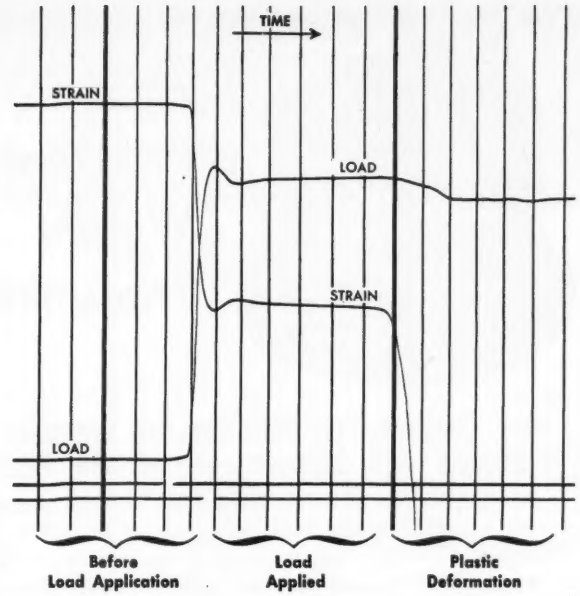


bandwidth, 4.3 Mc.; dimensions, 9.75 in. long, 0.875 in. wide, 1.25 in. high. Several lines may be assembled to provide additional delay.—*Tel-Instrument Co., Inc., 50 Paterson Ave., East Rutherford, N. J.*

Mention No. 956 when filling out card.

Three-circuit Plug and Receptacle

New three-circuit plug and receptacle combination has bodies of both parts molded of improved impact Durez



This record from a Consolidated 5-114 Recording Oscillograph gives an accurate, permanent answer to the question—

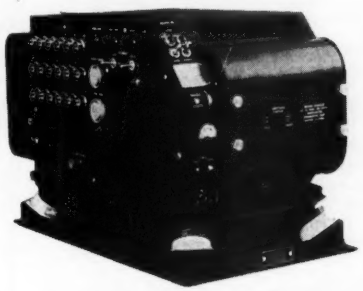
how long before metal stretches?

TO ANSWER this question, research engineers at California Institute of Technology have developed a rapid, tensile-testing machine capable of applying to a specimen any load up to 5 tons in 7 milliseconds. The problem is to measure the time delay between application of the load and the beginning of plastic deformation of metals.

Consolidated's Recording Oscillographs offer the practical solution to this problem. Recording load and deformation simultaneously, these instruments produce an accurate, high-speed picture of the time delay. Strain gages attached to the metal specimen and to the test machine yield exact signals for both deformation and load. By scaling the precise, 1/100th-second timing lines—automatically recorded by the oscillograph—against the trace deflections, the exact time delay is easily measured, although it lasts only a small fraction of a second.

Such problems of pure research, as well as the most practical field testing applications, are answered by Consolidated recording measurement instruments. The most universal of test equipment, they are as adaptable to highway bridges and box cars as to 1000 mile-per-hour aircraft.

Consolidated
RECORDING OSCILLOGRAPH



CEC's 5-114 Recording Oscillograph, recording up to 18 traces simultaneously on 7″-wide paper or film, is designed as the ultimate in precision, versatility, and operating convenience and incorporates many features available only through special accessories on many other oscillographs. Recording speeds from ½″ to 115″ per second, and easily removable feed-and-takeup record magazines of 125, 250, and 600-ft capacity offer an unusually wide application range. Write for Bulletin CEC 1500-X31.

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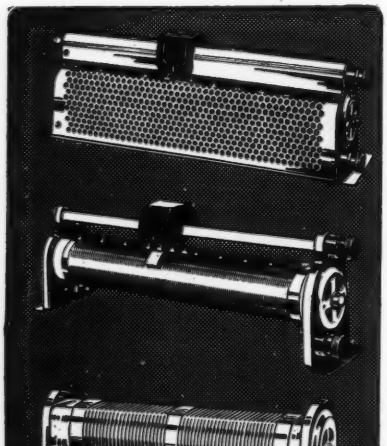

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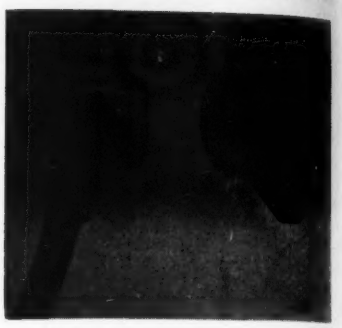
NEW INSTRUMENTS



phenolic. Receptacle has silver-plated silicon spring bronze contacts, dimpled for low-loss contact and proper registration of plug. Prongs are heavy silver-plated brass. Furnished with or without cord according to specifications. Rating is 15 amps. at 125 volts, 10 amps. at 250 volts, a.c. or d.c.—*Soreng Mfg. Corp.*, 9555 *Eden Ave., Schiller Park, Illinois.*

Mention No. 957 when filling out card.

Microwave Attenuator

New "Model SIJ" external broadband microwave attenuator operates on principle of a waveguide beyond cut-off; provides a range of attenuation in excess of 140 db; is designed to cover frequency range from 4000 to 12000 Mc.; has a 50-ohm impedance. —*Polarad Electronics Corp.*, 100 *Metropolitan Avenue, Brooklyn* 11, *N. Y.*

Mention No. 958 when filling out card.

Volume Controls

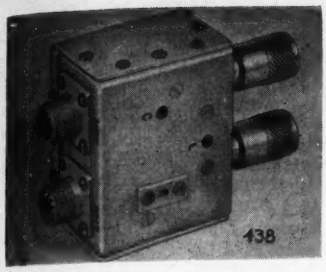
New "Series SWB" makes possible a new combination of control, switch and shaft, heretofore available with

1.125-in.-dia. volume control replacements, now extended to 0.9375-in.-dia. size. New smaller "Ad-A-Switch" has Underwriters' approval, is obtainable in s-p.s-t., three-way no "Off" position s-p.d-t. and d-p.s-t.—*Clarostat Mfg. Co., Inc., Dover, N.H.*

Mention No. 959 when filling out card.

Line Pad

New "Type V-102" video line pad in aluminum case with connectors for one or two line amplifier outputs, line input and monitor input, is designed to feed from a 73-ohm source to a 73-

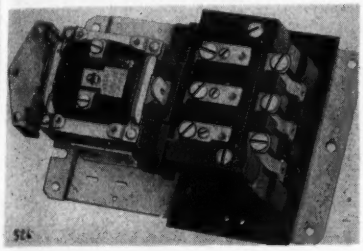


ohm line with zero loss; and provide a branch circuit containing 14 db of isolation for connection of a high-impedance monitor.—*The Daven Company*, 191 *Central Ave., Newark 4, N. J.*

Mention No. 960 when filling out card.

Solenoid Contactor

New "Bulletin 4458 Size O" a-c. solenoid contactors are designed for load and control circuit use. Contactors are available in 3- and 5-pole



forms. Contacts, housed in molded Melamine arc hood, can be interchanged to form N.O. or N.C. poles. New contactors can be furnished with d-c. power plants for 115 or 230 volt d-c. operation. Maximum hp. ratings are 2 hp., 440-550v., 3 ph. 60 cps. Open 8-hr. ampere rating is 15 amp.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

Mention No. 961 when filling out card.

Isolation Box

New non-powered isolation box, for use with "Tacoplex Antenna Distribution System," is housed in a Bakelite box the size of a standard outlet box. It contains a matching network of resistors providing an isolation factor between receivers of at least 30 db, with a minimum signal drop across outlet. Terminals are provided for 300-ohm twin-lead to receiver.—*Technical Appliance Corp., Sherburne, N. Y.*

Mention No. 962 when filling out card.

Subminiature Relays

New "Type MH" subminiature relays have been developed to meet requirements of USAF Spec. MIL-R-5757. Diameters: 6-pole, 1.1875 in.; 4-pole, 1.0325 in.; 2-pole, 0.625 in. For minimum chassis area, seated height for all three is 1.50 in. Operating range for "Standard Type MHB" is −55 C. to +85 C. and for "High-temperature Type MHA" is −65 C. to +200 C. New relays withstand 10-G vibration and 30-G shock of 10 milliseconds duration, as an operating condition. Hermetically sealed for operation to 70,000 ft. Nominal coil voltage is 26.5

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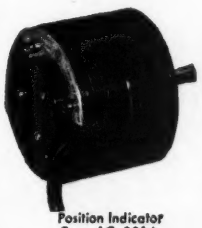
MICROSYNS



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Variable Inductor	offers an inductance that varies linearly with shaft rotation.

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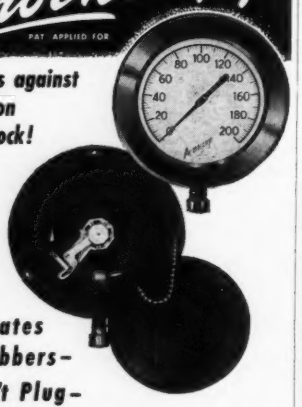

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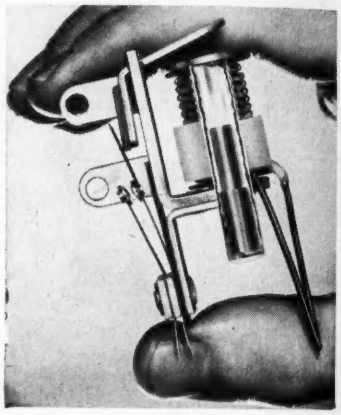
NEW INSTRUMENTS

volts d.c. but coils withstand overvoltage of 23 percent for 8 hours without damage. Contacts are rated at 2 amps. non-inductive at 28 volts d.c. for life expectancy over 1 million operations. Contact circuit resistance less than 0.02 ohm from terminal to terminal. —*Allied Control Co., Inc., 2 East End Ave., New York 21, N. Y.*

Mention No. 963 when filling out card.

Time Delay Relay

New "Silic-O-Netic" 10-amp. hydraulic-magnetic time delay relay utilizes an operating principle said to be new: a sealed tube, extending through and below relay coil, is filled with a

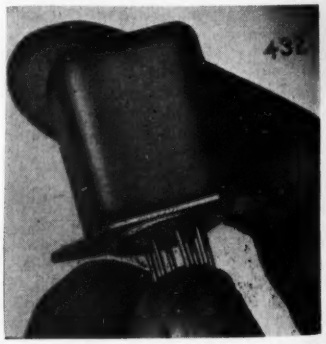


viscosity-stable silicone liquid, and holds a movable iron core. When coil is energized, movable core is drawn up into magnetic field, and its rate-of-rise is controlled by the silicone liquid. Relay operates on increased magnetic flux caused as core reaches pole-piece at top of tube. Units are available with timings up to 4 minutes. Timing is not appreciably affected by temperature or position changes.—*Heinemann Electric Co., 305 Plum Street, Trenton 2, N. J.*

Mention No. 964 when filling out card.

Sealed Relays

New "Series 5000" subminiature anti-vibration relays are now available in hermetically-sealed containers. They



withstand 20 g vibration and more than 50 g acceleration in any direction without affecting contact position. Illustrated is "Model 5610," an s-p.d-t. type with coils available in ratings from 3

to 72 volts d.c., and resistances from 8 to 5000 ohms.—*Neomatic, Inc.*, 11632 *San Vicente Blvd., Los Angeles* 49, *Calif.*

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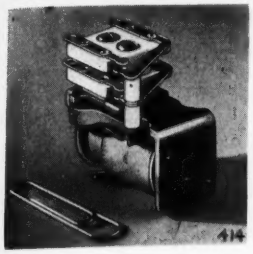
Low-capacitance Relay

New low-loss midget relay has 2.5-uuf. max. capacitance between contacts and to ground. Can be furnished with



single-pole normally-open or normally closed; 2 pole N-O or N-C; and s-p.d-t. Max. rating 3 amperes non-inductive at 28 volts d.c. (Two-pole N-O relay is illustrated). Also available up to 4-pole d-t. in standard contact arrangement.—*R-B-M Div., Essex Wire Corp., Logansport, Indiana.*

Mention No. 966 when filling out card.

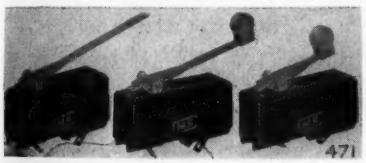
AGC Strip

New "No. 1562" automatic gain compensator strip for use with "Tacoplex" System, compensates automatically for changing signal strength by means of a detector and filter for developing a bias voltage proportional to signal output. Bias voltage is fed to a four-tube amplifier strip connected to antenna. Strips come tuned for any one of the 12 TV channels or FM band.—*Technical Appliance Corp., Sherburne, N. Y.*

Mention No. 967 when filling out card.

Lever-actuated Switches

New "V" series of maker's basic "Type A" switches have higher capacity than previous series, being rated by Underwriters Laboratories for 0.75-hp.



115 v.a.c., 1.5-hp. 230 v.a.c.; 20 amps. 125, 250 or 460 v.a.c.; 10 amps. 125 v.a.c. "L" ("L" being a-c. filament-lamp load). Contact-break distance 0.02 in.; contact arrangement s-p.d-t.—*Micro Switch, Freeport, Ill.*

Mention No. 968 when filling out card.

Miniature Rotary Switch

New miniature rotary switch, for miniaturized airborne equipment, is said to lend itself to applications previously considered impractical. Ganging one-, two- or three-pole switches offers combinations for complex cir-

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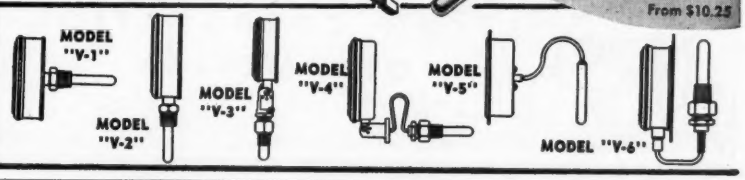

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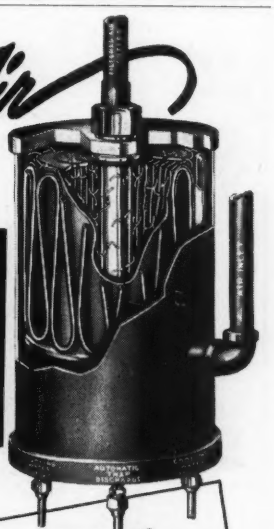

For maximum protection of air-operated instruments against oil, water, sludge and foreign materials, the New Hankison Model B-30 Condensifilter features a dehydrating device—a mechanical filter—and a self-purging trap in a single compact unit. Only 15" high and 9" in diameter, this unit will clean and dry compressed air at the rate of 30 c.f.m. at 100 psi. Larger models available for greater capacities.

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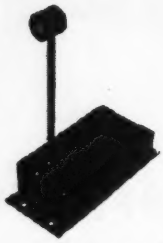

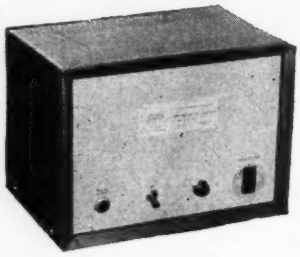

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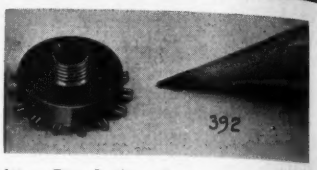
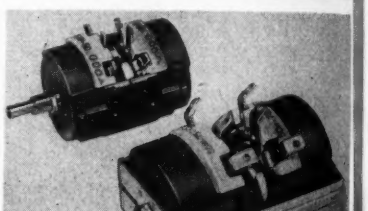


cuits. Insulation between shaft and contact arms will withstand 2,500 volts a.c. Diam., 5/8"; switch body 3/16" thick. Plastic parts compression molded of Plaskon Alkyd, said to be 9 times more resistant to arcs than phenolics. Contacts are pure silver; contact arm silver-plated heat-treated beryllium-copper.—*Electro Development Corp., 6014 W. Washington Blvd., Culver City, Calif.*

Mention No. 969 when filling out card.

Precision Dual Rheostats

New dual VDR's "Model 245" (25 watt each section) and "Model 241" (50 watt each section) feature all-metal construction for maximum heat



dissipation, metal winding core, stainless-steel insulated shaft, and copper graphite brushes. Available in high resistance ranges within 5 percent up to 50,000 ohms in 25-watt size, and 75,000 ohms in 50-watt size. Can be custom-built for step windings, tapered cards, special gaps, shorting bars, detent mechanisms, non-turn locking devices and slotted shafts.—*Industrial Div., Sec. IN, DeJur-Amsco Corp., Long Island City, N. Y.*

Mention No. 970 when filling out card.

Subminiature Resistor

New "Type WW-10" resistor is intended to pack as much resistance as possible into smallest possible space. Available in values from 10 ohms to 0.160 megohms. Rating 0.15 watt at 85 C. ambient; maximum temperature coefficient 0.0025 percent per deg. C.

from 20 C. to 100 C. Maximum voltage 150.—*International Resistance Co.*, 401 *N. Broad St., Philadelphia 8, Pa.*

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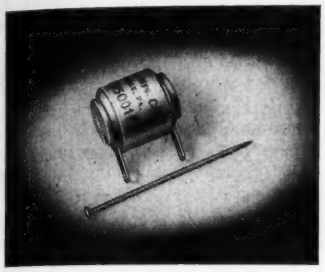
Miniature Resistors

New "Akra-ohm Type 1180" miniature hermetically-sealed resistors with solder lug terminals and designed to



meet requirements of JAN-R-93, characteristic A, style RB11, are 0.594 in. long x 0.5 in. diameter and are rated 0.25 watt at 250 volts. Resistance values up to 0.1, 0.3 or 0.4 megohms; non-inductive winding.—*Shallcross Mfg. Co., Collingdale, Penna.*

Mention No. 972 when filling out card.

TECHNICAL SOCIETIES

ASME SYMPOSIUM ON HIGH PRESSURE

The Industrial Instruments and Regulators Division of the American Society of Mechanical Engineers announces that plans are rapidly developing for its High Pressure Symposium to be held during its Annual Meeting at Cleveland, Ohio, September 8-12, 1952. Although the instrumental side of high pressure work will be stressed, a well-rounded program will be presented, covering all fields of interest relating to current operations in the pressure range from 10,000 to 150,000 psi. Papers are being solicited on the design of instruments for measuring pressures and for measuring the physical properties of materials in this range.

The tentative program includes papers in the following groups:

I *Survey and Historical*
II *Measurements*
III *Properties of Materials*
IV *Pressure vessels*
V *Pumps and plumbing*

It is expected that the Symposium papers will be published in a single volume, which will then represent the current state of knowledge on high pressure technology.

Mr. W. H. Howe, Chief Engineer, The Foxboro Company, Foxboro, Mass., will be in general charge of arrangements for the Symposium. Interested authors are requested to submit an abstract of their proposed papers to Mr. Howe as early as possible. Deadline for completed manuscripts is May 1, 1952.

SOCIETY FOR APPLIED SPECTROSCOPY

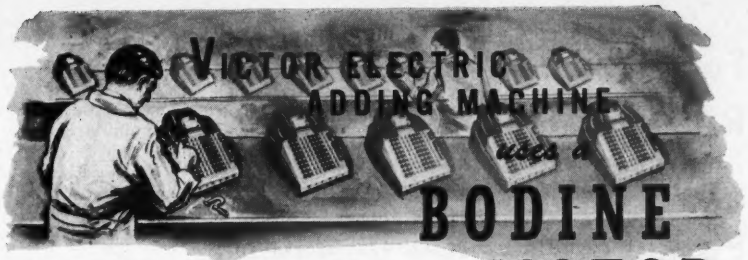
The October meeting of the Society for Applied Spectroscopy will be held on Tuesday, October 2. 6:00 p.m., informal dinner, Tosca's, 118 Fulton St., New York, no reservation necessary. 8:00 p.m., regular meeting, Socony-Vacuum Training Center, 63 Park Row, N. Y. C., Speaker, Dr. H. P. Schwarz, Div. of Biochemistry, Philadelphia General Hospital, Subject, Infrared Spectroscopy of Tissues.

OTHERS

AIEE Conference on Aircraft Equipment, Hotel Cleveland, Cleveland, Ohio, October 22-26, 1951.

Society for Experimental Stress Analysis, Annual Meeting and Exhibit, Bellevue Stratford Hotel, Philadelphia, Pa., November 28-30, 1951.

National Electronics Conference, Edgewater Beach Hotel, Chicago, Ill., October 22-24, 1951.



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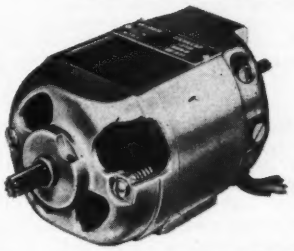
If you have a motor application problem, it will pay you to consult Bodine engineers.



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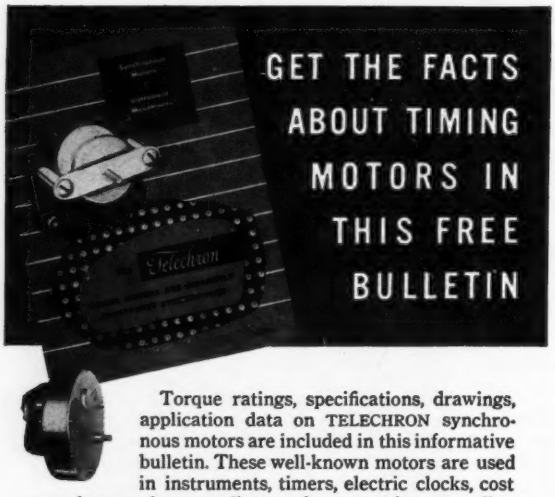

Torque ratings, specifications, drawings, application data on TELECHRON synchronous motors are included in this informative bulletin. These well-known motors are used in instruments, timers, electric clocks, cost recorders, cycle controllers and many other recording devices. They are your guarantee of accurate, dependable, long-life service. Write now for your copy of Bulletin IS-120. Telechron Department, General Electric Company, 69 Union St., Ashland, Mass.

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ALL TELECHRON TIMING MOTORS ARE

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INSTRUMENT ELECTRONICS

Continued from page 1049

effect of linking two inductors is called mutual inductance (M) and is measured in henrys. The amount of mutual inductance between two circuits—that is, the voltage developed in one coil by a given rate of change of current in the other—depends on their size and shape, their relative positions, and the magnetic permeability of the medium between the two.

In Fig. 2-19, A, not all the lines of force set up by the coil on the left cut the turns of the coil on the right because the high reluctance (low permeability) of the magnetic circuit (air) causes most of the flux lines to follow paths which do not link the coil. The extent to which two inductors are coupled is expressed by a *coefficient of coupling* (k). This coefficient is unity when all the flux set up by one coil links the other; it expresses the ratio of the mutual inductance actually present to the maximum value obtainable with unity coupling.

The mutual inductance of two coils can be formulated in terms of the individual inductance and the coefficient of coupling:

$$M = k(L_1 L_2)^{1/2}$$

Thus, the mutual inductance of two coils, each with an inductance of 10 henrys and a coupling coefficient of 0.8, is

$$M = 0.8(100)^{1/2} = 8 \text{ henrys.}$$

Inductors in parallel.—The total inductance of inductors in parallel is calculated in the same manner as for resistors in parallel, provided the coils are far enough apart to make the effect of mutual inductance negligible.

Inductors in series.—When the coils are far enough apart to make the effect of mutual inductance negligible, inductors in series are added like resistors in series. However, when two inductors in series are arranged so that the field of one links the other, the net inductance is $L_1 + L_2 \pm 2M$. The plus-or-minus sign must be used in the expression because the emf. induced in one coil by the flux produced by the other can either aid or oppose the counter emf. produced by self-induction—depending on the way the coils are wound. If two series coils are arranged so that one can be rotated relative to the other to cause a variation in the coefficient of coupling, the total effective inductance can be varied continuously. Such an instrument, called a *variometer*, provides a variable inductance.

Transformers

Two coils with mutual inductance are called a transformer. The coil that produces the original magnetic field is called the *primary;* the coil in which the voltage is induced is the *secondary*. The secondary winding can have the same number of turns, more turns, or fewer turns than the primary.

As shown in Fig. 2-19,A only part of the flux produced by the primary of an air-core transformer links the secondary windings. The flux lines that do not cut the turns of the secondary coil are called *leakage flux*. As the leakage flux does not induce a potential in the secondary, leakage should be kept as low as possible. The leakage can be kept low if the two coils are wound on an iron core (Fig. 2-19,B). In an iron-core transformer the flux lines stay within the high-permeability core, and almost all of them link the secondary coil.

Turns ratio.—When an alternating current flows in the primary winding of a transformer, an alternating voltage is induced in the secondary. Whether the induced secondary voltage is higher or lower than the voltage that is applied to the primary depends entirely on the *ratio* of the number of turns in the secondary winding to the number of turns in the primary winding. If the secondary has more turns than the primary winding, the voltage induced in the secondary is increased. This is a *step-up* transformer. Likewise, if the secondary has fewer turns than the primary winding, the secondary voltage is lowered; this is a *step-down* transformer. The voltage relation is expressed by the following equation:

$$E_P/E_S = N_P/N_S,$$

where E_P is the voltage impressed across the primary

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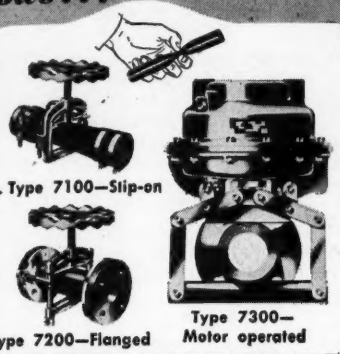

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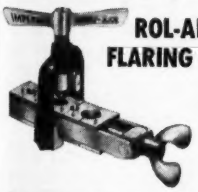

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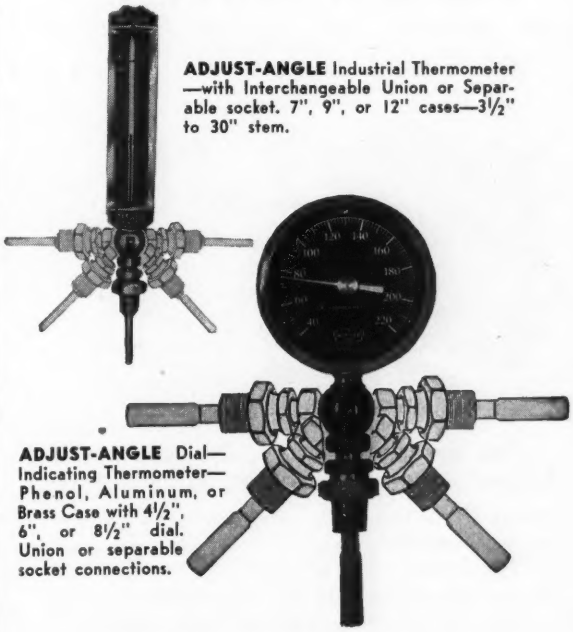

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winding, E_S is the voltage induced across the secondary winding, N_P is the number of turns in the primary winding, and N_S is the number of turns in the secondary winding (Fig. 2-19,B).

Fig. 2-20 shows a load resistor connected to the secondary of a transformer. Neglecting losses, the power supplied to the primary winding equals that delivered by the secondary winding to the load. Therefore, if the secondary voltage is stepped up, the secondary current must be reduced in order that the power remain the same. This leads to the following relation between the currents and turns ratio:

$$I_P/I_S = N_S/N_P.$$

Note that the primary and secondary currents are inversely proportional to their respective turns.

Consider the transformer circuit in Fig. 2-20. When the

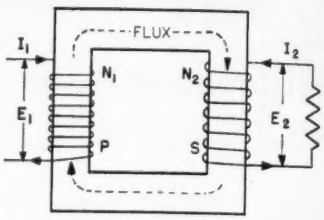

Fig. 2-20. Transformer with load resistor attached to the secondary.

load resistance across the secondary winding is changed, *both* the secondary and the primary current change. This is because the primary and secondary voltages are fixed by the turns ratio. Therefore, if the load resistance on the secondary is made smaller, the secondary current increases. This means that the secondary power is greater. As the primary circuit furnishes the power, the primary power also must increase. As the primary voltage is constant, the increase in power must be due to an increase in primary current. Thus, any time the secondary current increases or decreases for any reason, the primary current does likewise.

When no current is taken from the secondary (secondary unloaded) the current through the primary is small. However, a short circuit in the secondary causes an effective short circuit in the primary.

It is possible to obtain transformer action with a single coil of wire. This is shown in Fig. 2-21. The primary can be the total coil (A-C) and the secondary can be tapped off at some intermediate point on the coil (B-C). This type of transformer is known as a step-down *autotransformer*. An

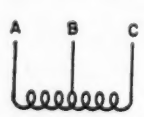

Fig. 2-21. Autotransformer.

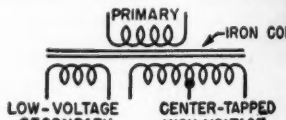

Fig. 2-22. Iron-core transformer with two secondaries.

autotransformer can be used either as a step-up or as a step-down transformer. When used as a step-up transformer, the input is applied across a portion of the whole, and the entire winding is the secondary. The current and voltage relations depend on the number of turns in the primary and secondary, as in any transformer.

One of the principal uses of transformers is to obtain voltages either higher or lower than that available in the power line. Transformers frequently are wound with several secondary windings to produce several output voltages (Fig. 2-22).

Transformer losses.—Transformers are efficient. The power output can be more than 99 percent of the power input. However, some power is lost owing to copper loss, hysteresis, and eddy currents.

Copper loss is simply heat caused by the current in the copper wires of the windings. This is minimized by using winding wires with sufficient current rating to carry the current without heating.

When iron is used as the core of a transformer, it is subjected to a varying magnetic field. The atoms of iron

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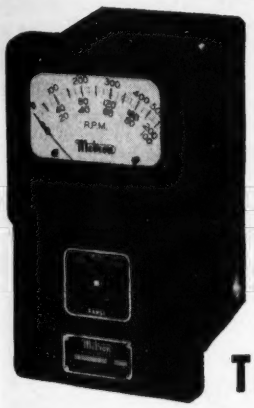

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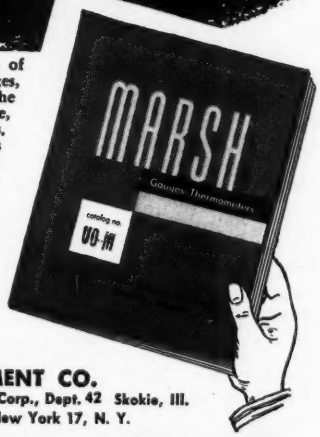

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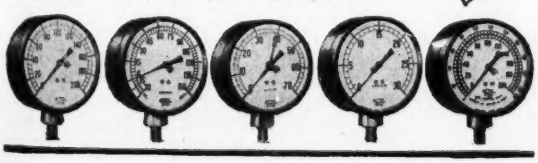

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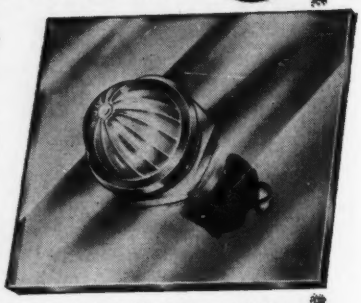
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do not easily change their positions, as is required when iron is magnetized. Therefore, a magnetic force is required to move them around. Some power is dissipated in changing the magnetism of the iron. Losses of this sort, which are called *hysteresis losses*, are a type of "magnetic friction" and, like mechanical friction, produce heat. Hysteresis losses are minimized by using soft iron with a high silicon content.

As iron is a conductor, circulating currents are induced in the iron core by the varying magnetic field. These currents, called *eddy currents*, represent a waste of power because they flow through the resistance of the iron and cause heating. Eddy currents are minimized either by dividing the iron into thin sheets, called *laminations*, which are insulated from each other, or by using powdered-iron cores. Laminations are used at low frequencies, such as 60 cycles per second; powdered-iron cores are used at frequencies up to 100 megacycles per second.

Eddy-current and hysteresis losses in iron increase rapidly as the frequency of the current is increased. Thus,

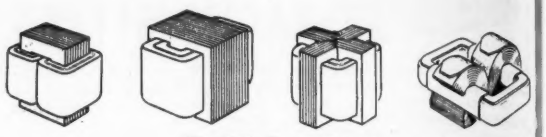

Fig. 2-23. Types of cores.

laminated iron cores can be used only up to about 15,000 cycles per second. At radio frequencies the magnetic field collapses and expands so rapidly that losses due to hysteresis and eddy currents are excessive. For this reason r-f. transformers have air cores or powdered-iron cores. Audio and power transformers use soft-iron cores because the core permits the transfer of energy from the primary to the secondary with high efficiency.

Transformer impedance.—The term "impedance" (Z) is used to describe the total opposition of a circuit element to flow of current—including both resistive and reactive opposition. Power equals I^2Z or E^2/Z.

If Z_P is the impedance of the primary of a transformer, and if Z_S is the impedance of the secondary, then the power in the primary of a transformer is E^2_P/Z_P; and the power in the secondary is E^2_S/Z_S. As the two powers are equal:

$$E^2_P/Z_P = E^2_S/Z_S$$

or

$$E_P/E_S = (Z_P/Z_S)^{1/2}$$

But

$$E_P/E_S = N_P/N_S$$

Therefore:

$$N_P/N_S = (Z_P/Z_S)^{1/2}$$

or

$$Z_P/Z_S = (N_P/N_S)^2$$

This is important in that it shows that a transformer can provide any desired secondary impedance by choice of turns ratio. For this reason transformers are used commonly to couple two circuits of different impedances.

Transformer types.—There are three general types of transformers.—power, audio frequency, and radio frequency. Power transformers are designed to operate at a fixed frequency—the frequency of the power source, usually 60 cps. Audio-frequency (a-f.) transformers are designed to operate over the audio frequencies to which the ear is sensitive—from about 50 to 15,000 cps. High quality a-f. transformers have uniform response over the entire a-f. band of frequencies. Radio frequency (r-f.) transformers are designed to operate at frequencies above audio frequencies. R-f. transformers usually have air or powdered-iron cores, whereas power and a-f. transformers have soft-iron cores.

Cores are made in various ways, as shown in Fig. 2-23. Note that the core provides the flux with a closed path of low reluctance.

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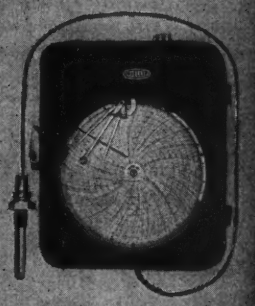

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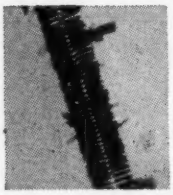

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formers sometimes are designed to operate at low signal level and, therefore, they must be well shielded against pickup caused by stray magnetic fields, particularly 60-cps. fields. This shielding usually is done by use of concentric magnetic shields of high-permeability nickel alloy.

Transformers often are sealed hermetically against moisture in the atmosphere.

Uses of Inductors

Inductors are used in five basic ways—as frequency-responsive elements, as voltage-changing and impedance-changing devices, as coupling devices, as an element in a resonant circuit, and as saturable reactors. The use as a frequency-sensitive element arises from the fact that the reactance of an inductor increases with frequency. Thus, an inductor in series with the signal can pass direct current or low-frequency alternating current and block high-frequency alternating current. Note that this action is opposite to that of the capacitor, which passes alternating current and blocks direct current.

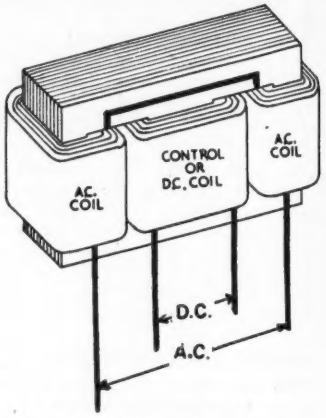

Fig. 2-24. Saturable reactor.

Inductors are used in transformers to change the voltage level or the impedance level of a signal, as has been described. Special transformers, called *instrument transformers* are available for use with both a-c. ammeters and a-c. voltmeters for changing the scale range of the instruments. A *potential transformer* is used with a voltmeter; a *current transformer* is used with an ammeter.

Either the autotransformer or the conventional transformer can be used to couple a signal from one circuit to another. This is a common use for inductors, particularly when the impedances of the two circuits differ.

Inductors are used commonly in conjunction with capacitors to form resonant circuits, as will be explained later.

Saturable reactor.—Special reactors are made which use the saturable feature of a magnetic core. The counter emf., and hence the reactance, of an inductor depends on a change of flux. When the core is saturated the flux does not change when the current through the inductor changes. Therefore, no counter emf. accompanies the current change, and the reactance of the inductor with a saturated core falls to zero.

In *magnetic amplifiers*, the core saturation is controlled by a small direct current in one winding on the core (Fig. 2-24). A secondary winding on the same core can pass large or small alternating currents, depending on its reactance. Thus a small current in one winding of the reactor controls a much larger current in another winding. This makes the saturable reactor a "magnetic amplifier." Such amplifiers use a core material of high permeability, which saturates easily.

A saturable core is used also in *constant-voltage transformers*. The core is saturated moderately so that the output voltage of the transformer remains constant over a given range of applied voltage.

Test Items on Part 2,—Inductance, on page 1088. Answers to Quiz II, Part 1,—Resistors and Capacitors, on page 1090.

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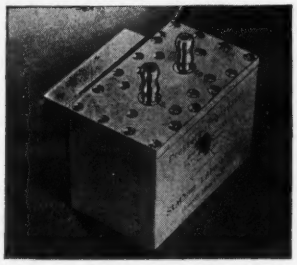

The Model P69 pressure transducer is designed for long life and excellent performance under conditions of vibration and acceleration such as are encountered in flight test and guided missile applications. This dynamically balanced, temperature compensated transducer is offered for the measurement of gage, differential, or absolute pressure. The full bridge of the transducer will operate successfully with a wide variety of controlling, indicating, recording, and telemetering circuits.

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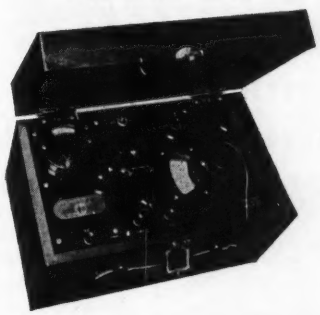

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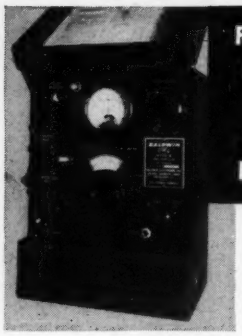

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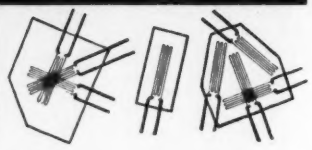

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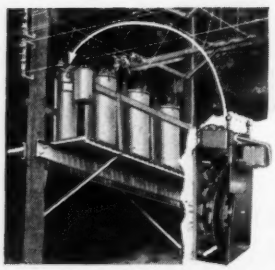

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TEST ITEMS FOR—II. CIRCUIT ELEMENTS
Part 2.—Inductance

2-27. Inductance is associated with a
(a) stationary electric field
(b) stationary magnetic field
(c) changing electric field
(d) changing magnetic field

2-28. A magnetic field is represented by
(a) voltage vectors
(b) current lines
(c) flux lines
(d) rotating vectors

2-29. The opposition offered by any material to the development of a magnetic field within that material is called
(a) resistance
(b) reluctance
(c) permeability
(d) hysteresis

2-30. A low reluctance is equivalent to a high
(a) resistance
(b) capacitance
(c) permeability
(d) hysteresis

2-31. A high magnetic field can be produced easily in a material with
(a) low resistance
(b) high resistance
(c) high reluctance
(d) high permeability

2-32. As the current in a coil with a magnetic core is increased, the magnetic field around the coil increases
(a) without limit
(b) until the core is saturated
(c) until the core is magnetized
(d) until the current rating of the core is reached

2-33. The permeability of air is about
(a) 1
(b) 100
(c) 1000
(d) 10,000

2-34. The permeability of Permalloy is about
(a) 100
(b) 6000
(c) 80,000
(d) 413,000

2-35. Hysteresis is caused by
(a) residual magnetism
(b) permanent magnetism
(c) core saturation
(d) inductance

2-36. The unit of inductance is the
(a) farad
(b) ohm
(c) henry
(d) reactance

2-37. Inductance is defined in terms of the counter emf. caused by a given
(a) current
(b) voltage
(c) rate of change of current
(d) rate of change of voltage

2-38. Coil A has the same number of turns, the same cross-sectional area, and the same core as coil B. However, coil A is twice as long as coil B. The inductance of coil A is
(a) twice that of B
(b) the same as B
(c) ½ that of B
(c) ¼ that of B

2-39. Which of the following phase relations between the current through and the voltage across a pure inductor is true?
(a) current leads voltage by 90 degrees
(b) current leads voltage by 180 degrees
(c) voltage leads current by 90 degrees
(d) voltage leads current by 180 degrees

2-40. An inductor differs from a capacitor in that it has
(a) no reactance
(b) no power loss
(c) a reactance which decreases with frequency
(d) different phase relations

2-41. A transformer with 100-percent efficiency has a coefficient of coupling of
(a) 100
(b) 10
(c) 1
(d) 0.01

2-42. A variometer is an instrument which provides a variable inductance by changing the
(a) permeability of the core of a coil
(b) number of turns of one coil
(c) turns of two coils
(d) coefficient of coupling of two coils

2-43. When a fixed voltage is applied across the primary of a transformer, the current in the primary depends primarily on the
(a) voltage across the primary
(b) voltage across the secondary
(c) current in the secondary
(d) turns ratio

2-44. When a fixed voltage is applied across the primary of a transformer, the voltage across the secondary depends on
(a) the turns ratio only
(b) the number of primary turns only
(c) the number of secondary turns only
(d) the secondary current only

2-45. An autotransformer differs from a conventional transformer in having
(a) no primary
(b) no secondary
(c) only one coil
(d) an iron core

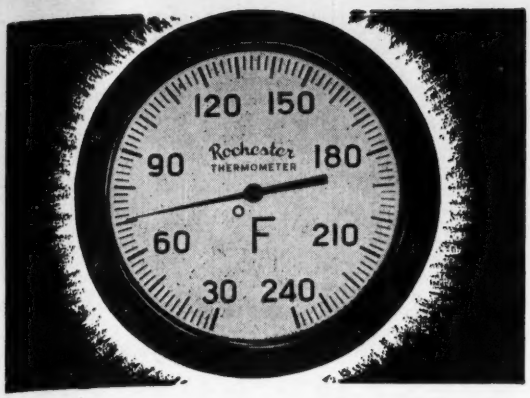
2-46. Use of large-size wire in the windings of a transformer minimizes
(a) copper loss
(b) hysteresis loss
(c) eddy-current loss
(d) all the above

2-47. An advantage of soft-iron core is the
(a) high efficiency of transformer action
(b) low eddy currents at high frequencies
(c) low hysteresis at high frequencies
(d) all the above

2-48. An advantage of a powdered-iron core over a soft-iron laminated core is
(a) higher efficiency at low frequencies
(b) reduced losses at high frequencies
(c) higher reluctance
(d) greater hysteresis effect

2-49. Eddy currents in a transformer occur primarily in the
(a) primary
(b) secondary
(c) core
(d) magnetic field

2-50. A step-up transformer has a turns ratio of 10 to 1 and a primary impedance of 1000 ohms. The secondary impedance is
(a) 1,000,000 ohms
(b) 100,000 ohms
(c) 1000 ohms
(d) 10 ohms



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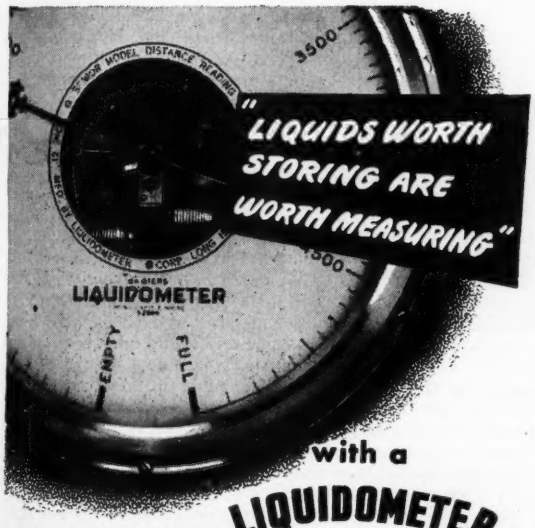

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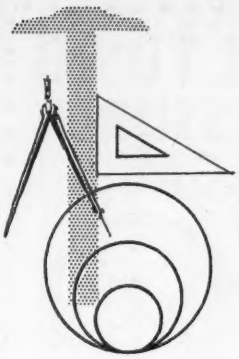

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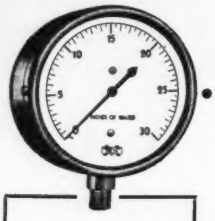

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2-51. The reactance of an inductor
- (a) increase linearly with frequency
- (b) decreases linearly with frequency
- (c) is independent of frequency
- (d) decreases as the square of frequency

2-52. Transformers used to change the range of a-c. voltmeters and ammeters are called
- (a) autotransformers
- (b) coupling transformers
- (c) range changers
- (d) instrument transformers

2-53. A core of a coil is said to be saturated when an increase in current through the coil causes
- (a) a large change in flux
- (b) large eddy currents
- (c) no change in flux
- (d) no eddy currents

2-54. The reactance of a coil with a saturated core is
- (a) $2\pi FL$
- (b) $(2\pi FL)^2$
- (c) zero
- (d) maximum

2-55. In a magnetic amplifier, a small current controls a larger current by controlling the
- (a) saturation of a core
- (b) turns ratio of transformer
- (c) mutual coupling of a transformer
- (d) electron flow through a core

2-56. The core of a magnetic amplifier should
- (a) have high reluctance
- (b) have high permeability
- (c) be difficult to saturate
- (d) have large hysteresis effect

ANSWERS TO QUIZ II (Part 1)

2-1. (b)	2-7. (c)	2-12. (a)	2-17. (a)	2-22. (d)
2-2. (d)	2-8. (d)	2-13. (d)	2-18. (d)	2-23. (b)
2-3. (a)	2-9. (c)	2-14. (b)	2-19. (c)	2-24. (a)
2-4. (c)	2-10. (c)	2-15. (a)	2-20. (b)	2-25. (d)
2-5. (a)	2-11. (b)	2-16. (d)	2-21. (b)	2-26. (c)
2-6. (a)				

PRESS BRAKE RAM MOTION CONTROL

Continued from page 1053

by an amplidyne generator, which is controlled by the photoelectric system. Any tilt of the ram raises or lowers a barrier suspended between the photocell and the light source. Movement of this barrier as much as a thousandth of an inch results in automatic correction through altered speed and direction of the oil flow from the transfer pump. Vertical micrometer adjustment of the control unit permits the ram to be operated at a selected degree of tilt when required. According to Verson engineers, the electronic ram control is more efficient, more sensitive and easier to operate than the mechanical tie or valve-and-limit-switch methods.

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Aimed primarily at audiences composed of people whose understanding of industrial instrument application would be enhanced by a sweeping view of the whole field, the film achieves a nice balance between education and entertainment. For professional instrument men and undergraduates of technical and engineering schools, there are sequences demonstrating control effects, instrument manufacture and instrument application. Instrument men operating in one industry can see in this film how instruments are applied to other industries. For science classes in high schools or colleges, there are scenes relating products such as food, film, plastics, petroleum and chemicals to controlled processing techniques. For the diversified audience, the intricate steps in the manufacture of a mercury-in-glass thermometer are shown. The film is keyed so that any audience will carry away with it a keener appreciation of the extent to which instruments play a major role in the welfare of mankind.

Script for the film was written by Oeveste Granducci of Washington, D. C. The producer is McLarty Picture Productions of Buffalo, N. Y. Requests for loan by technical societies, instrument engineers, science classes, civic clubs, etc., should be made to: Taylor Instrument Companies, Public Relations Dept., 95 Ames St., Rochester, N. Y.

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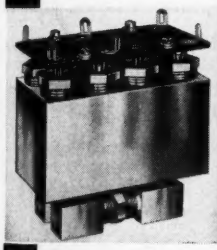

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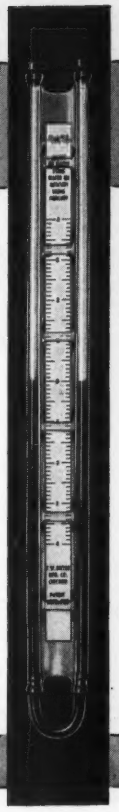

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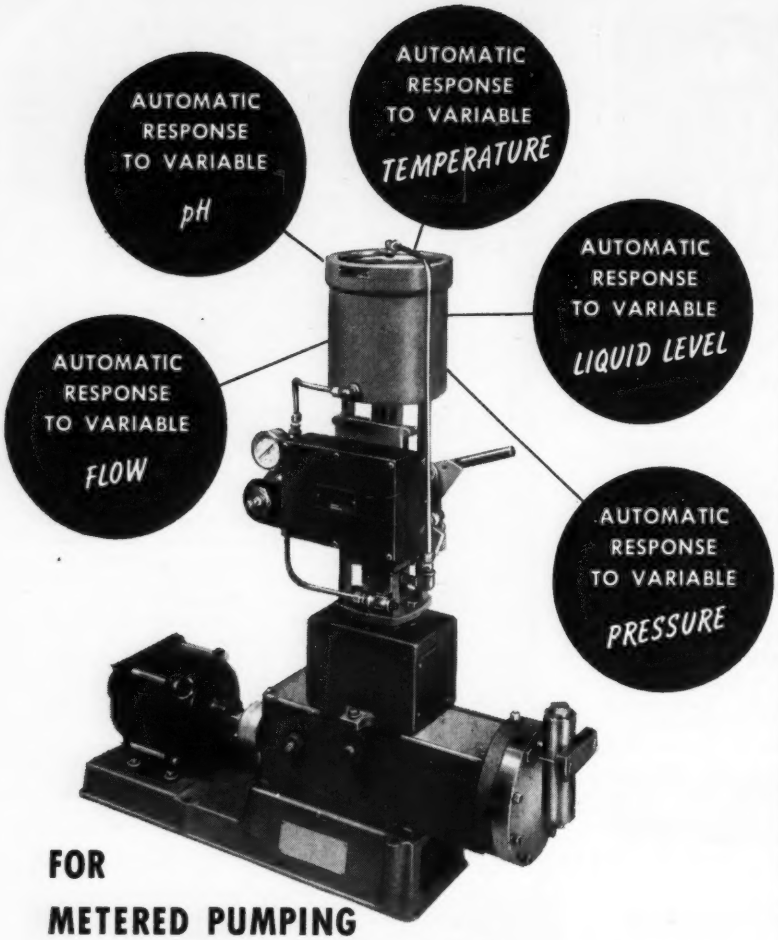
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EUROPE'S INDUSTRIAL AND INSTRUMENT FAIRS

Continued from page 1046

Men interested in instruments and measuring devices did not have enough time to see all the instrument exhibits in ten days; if they had to spend only one or two days, the trip was not worthwhile. Thus the present arrangement was not profitable for the instrument exhibitors. Further, if all the instrument exhibitors had been located in a single building, the general public would not have visited this building in large numbers. This would have conserved the time of the exhibitors' personnel.

Last year your publisher urged instrument manufacturers to be careful not to permit construction drawings and other data to fall into Russian hands. In this regard the Russians seem to have learned a new trick—to purchase an interest in European instrument companies. This is a most effective method to obtain such information or to sabotage the specific plant or company. Any indication of similar happenings in the United States should be reported immediately to the proper authorities.

The application of instruments in Britain lags behind the United States because the English are not sold instruments—"they buy them." An opinion prevalent abroad is that the American instrument salesmen sells the user more instruments than the user has need for.

Many buyers select instruments of several manufacturers for the same job. This is to prevent the "top brass" in his company from accusing him of partiality. Such a practice makes for the purchase of more instruments than are needed. There also is a practice among large European instrument users to tear down manufacturers' new models, which they cannot reassemble properly, thus making for improper operation.

The European user-industry executives do not have proper appreciation for their instrument engineers. These executives should be educated to recognize the value of the attendance of their engineers at the meetings devoted to instrumentation subjects and exhibits. At present, English executives are of the opinion that one-day attendance of their engineers is sufficient to see the products of 143 exhibitors using 42,000 square feet of exhibit space.

CORRECTION

On page 768 of the July Issue of *Instruments*, a line was omitted in the article by J. W. Percy. This line read: "Similarly, the error in the blow-tube type pyrometer is probably not more than ± 12 F." The line should have appeared immediately after "± 7 F." in the 7th line under *accuracy*.

Published by SCHUTTE and KOERTING Company

ENGINEERING News

SK ROTAMETERS HELP PROVIDE CLOSE CONTROL IN VITAMIN A PROCESSING

(Photos and Story By Courtesy of Chas. Pfizer and Co., Inc.)

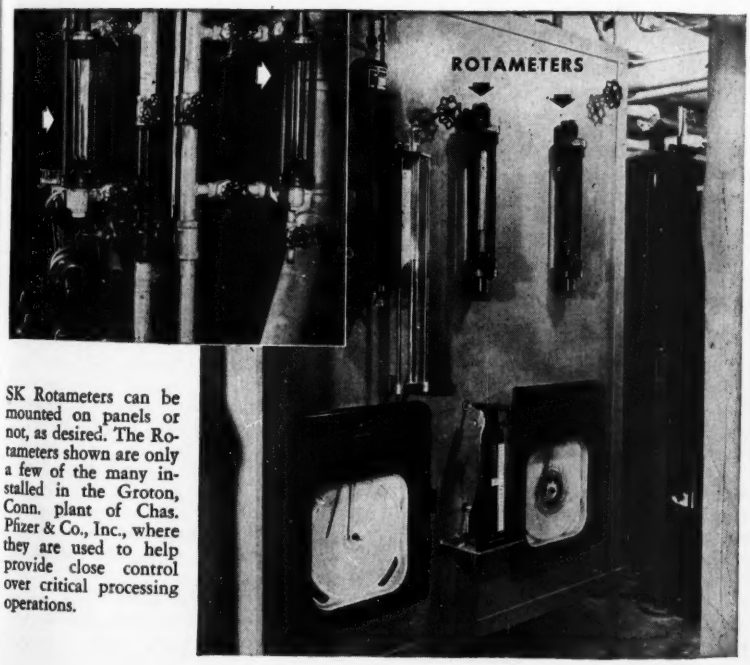
On March 19, 1951, Chas. Pfizer & Co., Inc., 102-year-old Brooklyn chemical firm, announced that stabilized crystalline Vitamin A Acetate was being produced by synthesis on a commercial scale for the first time in history.

Production of Vitamin A is being accomplished at the company's new two-million-dollar plant in Groton, Conn. which, when operating at full capacity, will be able to produce 50% of the U. S. need for this vitamin.

In this new plant, a large number of SK Universal Rotameters, accurate fluid rate-of-flow measuring instruments, are being used to help provide close control over critical processing operations.

SK Rotameters offer an ideal solution to many flow metering problems. They are not complicated in design — their principal components include a calibrated glass tube, a rotor, and a sturdy metal frame and end fittings. The gas or liquid being metered passes through the Rotameter tube from bottom to top. The rotor moves up or down in the tube as the rate of flow increases or decreases. Rate of flow is determined by reading the location of the top of the rotor against the uniform, etched calibration marks on the glass tube. Many fluid metering problems can be solved with the Universal type shown in the photos. However, many other types are available for measuring, recording, integrating, or controlling fluid flow.

For information on all types of SK Rotameters, request Bulletin 18-RA.



SK Rotameters can be mounted on panels or not, as desired. The Rotameters shown are only a few of the many installed in the Groton, Conn. plant of Chas. Pfizer & Co., Inc., where they are used to help provide close control over critical processing operations.

The SK ENGINEERING NEWS is published quarterly in magazine form. Recent issues have contained many informative articles relating to fluid flow measurement and control. You can have your name added to the list of those who regularly receive the NEWS by writing to this company.

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"A Method *for* Correcting Orifice-meter Measurements *for* Flow Pulsations"

(By E. V. Hardway, Jr., *Instruments*, July 1951, pages 763-765, 774, 775.)

To the Editor of *Instruments*:

The article on "A Method for Correcting Orifice Meter Measurements for Flow Pulsations" by E. V. Hardway Jr. in the July 1951 issue of *Instruments* is very interesting. With the exception of installation conditions, it is probable that the determination of errors due to pulsation has been the largest source of difficulty in flow measurement by inferential methods. Any logical method which gives promise of solving this problem should be given very close study and attention.

However, I believe that this article is based upon an assumption which I believe does not hold for all cases and possibly holds for very few of them. That is the statement made that "The principal cause of pulsation error is the fact that the meter mechanism cannot follow the rapid pulsations and consequently indicates *average* differential pressure."

From this I would understand that the difference between a pulsating flow and one which is merely rapidly fluctuating arises when the meter mechanism is no longer able to follow the variations in flow. Based upon actual experience, and some of the previous investigation done in this field, I do not believe that this is necessarily the case. This reasoning does not take into account the resonant effect in the lead lines to the meter bodies, nor the fact that such resonant effect will change both with frequency and with displacement of the measuring element of the meter. As evidence of this I would like to offer the three following examples from my own experience:

1. On a dead-end line, into or out of which there was no effective flow, an ordinary mercury float type differential pressure gage showed very erratic readings, sometimes reading as though there were flow into the line, and sometimes reading as though there were flow out of the line, and other times showing no flow either into or out of the line, which was correct.

2. On a steady liquid flow from a reciprocating pump, the pen of a recording pressure differential gage would start at the zero circle and slowly rise to the outside edge of the chart over a period of about fifteen minutes. It would stay at the outside edge of the chart for approximately five minutes and then drop rapidly to the center, where it would stay for another two or three minutes, and then start up again. The chart was a perfect "sunflower" type. This was on a charge pump to a pipe still, and it was known from the operation of the still that the flow was perfectly steady. In this case, this was corrected by changing the length of one of the lead lines, after which the meter showed the true flow, as checked by feedtank measurements.

3. On another installation on the feed to a pipe still, the flow was controlled by a flow controller maintaining a constant differential pressure across an orifice in the discharge of a reciprocating pump. The outlet temperature from the pipe still showed that the flow was changing in a small amount in a cycle of a period of approximately five minutes. The differential pressure record on the chart was perfectly steady, but after some period of observation, it was noticed audibly that the pump was changing speed in a cycle that corresponded to the temperature cycle from the pipe still outlet. Upon putting the controller on remote hand control the pump ran steadily, and a cycle appeared on the chart which corresponded in period to the former temperature cycle, and was of a magnitude of about 3 percent of the flow. This was corrected by opening a bypass between the pump discharge and suction, which caused the pump to have to run faster in order to maintain the same rate of flow to the still. Doing this broke up the resonance, and both the flow record and the temperature record became constant. In this case, maintaining a constant differential pressure produced an actually varying flow.

The article does not cite any references to installations where this method has been applied successfully, and it would be very interesting to know that the theories were backed up by actual experimentation and practical experience. Many suggestions have been made concerning this problem, and rather large amounts of money have been spent in an attempt to cure it. If the method suggested is practical, then the proofs of that should be given in the form of citations of actual successful installations.

J. B. McMahon,
Republic Flow Meters Co.
Chicago, Aug. 6, 1951

To the Editor of *Instruments*:

Mr. McMahon's comments are very much appreciated. It is believed, however, that he may have overlooked several important points brought out in the article. First of all the method, as stated, is limited to moderately pulsating conditions *where flow reversals do not occur*. The suggested method is intended for the quantitative determination of errors less than seven percent *and* the indication of whether or not the pulsating conditions are causing errors greater than 7 percent, making accurate measurements impossible.

Mr. McMahon's first example is concerned with a special and not a practical case in which 100 percent flow reversals occur, and thus has no bearing on the validity of the proposed method. The curves in Fig. 2 show how the error increases rapidly near the point where flow reversals occur. For 100 percent reversals, even slight and varying asymmetries in the pulsation could readily cause the erratic behavior described in his first example. His other two examples appear to be cases in which peculiarities in the installation or the meter mechanisms themselves played a predominant part. His third example is somewhat difficult to understand inasmuch as he states that the pump (and the flow rate) were subject to cyclic variations whereas the flow controller was unaffected. Inasmuch as the flow controller was governing the flow rate, it is difficult to see how this was possible. Undoubtedly, critical resonant conditions were present at the pump output frequency. This does not however, invalidate the method proposed or prove that the cyclic errors would not have been properly indicated.

In general, Mr. McMahon disagrees with the statement that the *primary* cause of error is the fact that the flow is determined from the integrated square-root of the average pressure rather than the integrated instantaneous square-root. I would like to point out here that the method of approach used was based on the general conclusion of many prior investigations in this field with considerable practical experience in the determination of the causes of pulsation error.

In a series of AGA-ASME sponsored tests for the purpose of correlating pulsometer reading, meter differential and meter error, approximately 500 tests were performed on 2-, 4-, and 6-in. lines under a wide variety of conditions. The pulsometer curve for determining whether or not the errors were greater or less than 1 percent was thus empirically determined. This curve checks the theory (based on the assumption Mr. McMahon does not accept) very closely. Also, the conditions for one percent error taken from Fig. 3 in the article check very closely with the pulsometer empirical curve for the same conditions. This would either be a remarkable coincidence, or the burden of disproof would fall on Mr. McMahon. The above tests are described in Reference 1 of the article.

It is well to re-emphasize here that what the proposed method essentially does is to take account of both waveform and random amplitude variations, thus making it possible to extend the useful range of error determination to seven percent, which is considered the upper limit with relation to the severity of the pulsations.

The problems associated with unequal line volumes, discharge and entrance coefficients, etc., although mentioned in the next-to-last paragraph of the article, were not discussed at length because they have been discussed elsewhere in several of the references. I certainly agree with Mr. McMahon that these causes of error should be kept in mind in the layout of any installation likely to be subject to pulsation errors. It also would seem perfectly possible that at some installations such errors would add to the primary error causing the actual error to be somewhat greater than that indicated by the method. It is, however, common instrumentation practice to eliminate systematic errors insofar as possible and do all that is practically possible to eliminate the cause of uncertainties. It would not seem the best approach to ignore the primary cause of error because other lesser sources of error appear to be beyond our control. Again I refer to conditions specified in the article which are believed to be most common, for example on gas transmission lines.

With regard to Mr. McMahon's last paragraph, I wish to point out that no pretense was made in the article that a full-scale evaluation program has yet been conducted. Such tests, to be adequate, would be both elaborate and expensive (Ref. 1), and would require the cooperation of an operating transmission company and preferably one or more of the professional societies. The writer would certainly welcome the opportunity to participate in such a program to establish the validity of the method outlined.

In conclusion, it is believed that sufficient experimental and theoretical evidence exists to justify the adoption of the proposed method. As Mr. McMahon's comments illustrate, particular care must be employed in the layout of metering installations, particularly where liquids are being metered, to minimize other sources of error peculiar to the installation or the meter mechanism.

E. V. HARDWAY, JR.,
THE BETA CORPORATION
Richmond, Va., Aug. 20, 1951

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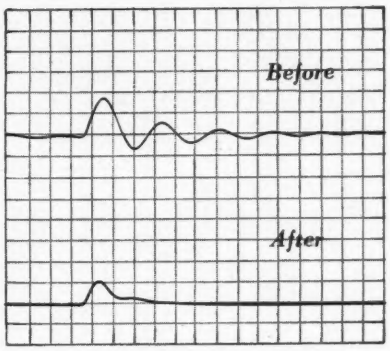

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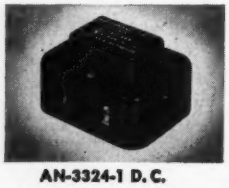

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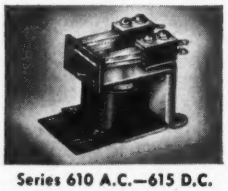

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THE SECRETARY'S PAGE

Richard Rimbach

THE Secretary has recently received a letter from Mr. R. A. Trenner, Philadelphia Section Secretary which is quoted below:

"The Philadelphia Section of the ISA is sponsoring a Symposium on Boiler Instrumentation to be held on Thursday, November 15, 1951 at the Bellevue Stratford Hotel in Philadelphia. We are planning to make this a one day conference and we are inviting the IIRD Group of the ASME to participate in this Symposium with us at least from the standpoint of their attendance.

This Symposium has been in its planning stage for approximately the last five months and when we received the notification from the New York Section of the ISA that they were planning a Symposium on a similar topic for January 1952 to be held in New York City, we thought that we had gone to far along with our plans of obtaining speakers and like preparations for this Symposium for us to drop it and pick a new subject. We have explained this matter at some length with a letter to the Secretary of the New York Section and while we feel that the conflict in titles is regretable, we do not feel that there will be any drastic lack of attendance at either of these Symposiums due to the similarity in subjects for these two Symposiums. We found that in conducting our Symposium last November that our attendance was primarily local going from metropolitan Philadelphia and its immediate vicinity. If this is the type of attendance that we will obtain at our Symposium in November we cannot see how it will be detrimental as far as the attendance for the later Symposium in New York.

It is the suggestion of our Executive Committee that there be formed a "clearing house" at the National ISA in Pittsburgh for Symposium subjects so that upon planning a Symposium any section can be informed immediately as to what the subjects for the Symposiums for the coming year are to be, and thereby avoid any such happening such as we have had in the way of similarity of subject material for the two Symposiums, one in Philadelphia and the later one in New York.

We would like to take this opportunity to extend an invitation to you personally to attend our Symposium in November and hope that you will be able to be in our midst at that time."

Continued on page 1098

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
W. E. Bostwick, 2615 Sandia Dr., Bel Air, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:30 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge, La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 Onondaga St., Syracuse.

CHARLESTON
Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman, Rm. 1400 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Eng'r. Society Hqs.

CLEVELAND
G. D. Karnegie, 3436 Lorain Ave., Cleveland, Ohio.
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
E. H. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, 8:00 P. M., Dinner at 6:30 P. M., Algonquin Hotel.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

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A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.
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EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, Brown Instrument Co., 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., University of Houston.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., Dominion Square Bldg., Montreal, Quebec, Can. Tel: UNiversity 6-4725.
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

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Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

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Bert L. Anderson, 1951 47th Ave., San Francisco, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P. M., Spengers Grotto.

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J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-3, Apt. 214, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
W. F. Hoag, Phillips Chem. Co., Box 277, Dumas, Texas. Tel: 241.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 306, 3147 Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa. Tel. Express 1-1330.
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash.
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

THE SECRETARY'S PAGE

Continued from page 1097

This letter was discussed at the recent ISA National Executive Committee meeting in Pittsburgh, July 27 and 28, and the National Office was instructed to set up a "clearing house" for listing Symposia or Regional Meetings held by local Sections. Actually such a "clearing house" was established last fall when the New Jersey, New York, Philadelphia and Pittsburgh Regional Meetings were announced.

The Pittsburgh Meeting was devoted to "Instrumentation in the Steel Industry" and the next Symposium will be on the same subject and will be held April 3 and 4, 1952.

The above letter indicates that the Philadelphia Regional Meeting will be held on November 15, 1951 on Boiler Instrumentation. This is a change from the topic of last year's very successful meeting.

The New York meeting will also be held on Power Plant Instrumentation. A change from last year's successful meeting on Process Control.

The Secretary has recommended from time to time that the subject for such regional meetings should be the same each year. In that case the subject chosen should be one peculiar to the locality where the meeting is to

be held, or it should be governed by the number of individuals in the region interested in a certain subject.

Therefore any Section planning a regional meeting is urged to check the list of Regional Meetings being maintained in the National Office.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA 921 Ridge Ave., Pittsburgh 12, Pa.

DEVELOPMENT ENGINEER. To design and develop a workable instrument, operating from prescribed physical principles. The man required must have a general knowledge of engineering, including some electronics, mechanics, machine shop practice and the ability to undertake the rseponsibility of a development project. Salary is commensurate with ability and initiative. Location New Jersey. Box 516.

SERVICE ENGINEER. To service meters and controls in boiler plants of customers of well established sales organization. Engineering degree not necessary but applicant must have practical knowledge of meter and controls and should be willing to extend his schooling for further proficiency. Permanent position and excellent opportunity for young man wishing to specialize. Company has profit sharing trust and other incentives. Location Chicago, Ill. Box 517.

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SALES ENGINEER. Wanted by well established manufacturer of industrial thermometers, dials, recorders and controllers, to work out of its Detroit office. This is a genuine opportunity for an aggressive man experienced in instrumentation. State fully background, education and experience in first letter. Box 520.

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GOVERNMENT SERVICES

INSTRUMENTATION SCIENTISTS. A program in basic instrumentation research is underway at the National Bureau of Standards cooperatively sponsored by ONR, Air Force, and AEC, involving theoretical and experimental research development, design, evaluation, and technical reference work in the broad field of measurement and control instrumentation. Excellent opportunities are open for qualified scientists and engineers in a broad variety of basic instrumentation problems. Salaries range from $3825 to $7600 per year. Further information concerning these positions can be obtained from W. A. Wildhack, Chief, Office of Basic Instrumentation, National Bureau of Standards, Washington 25, D. C.

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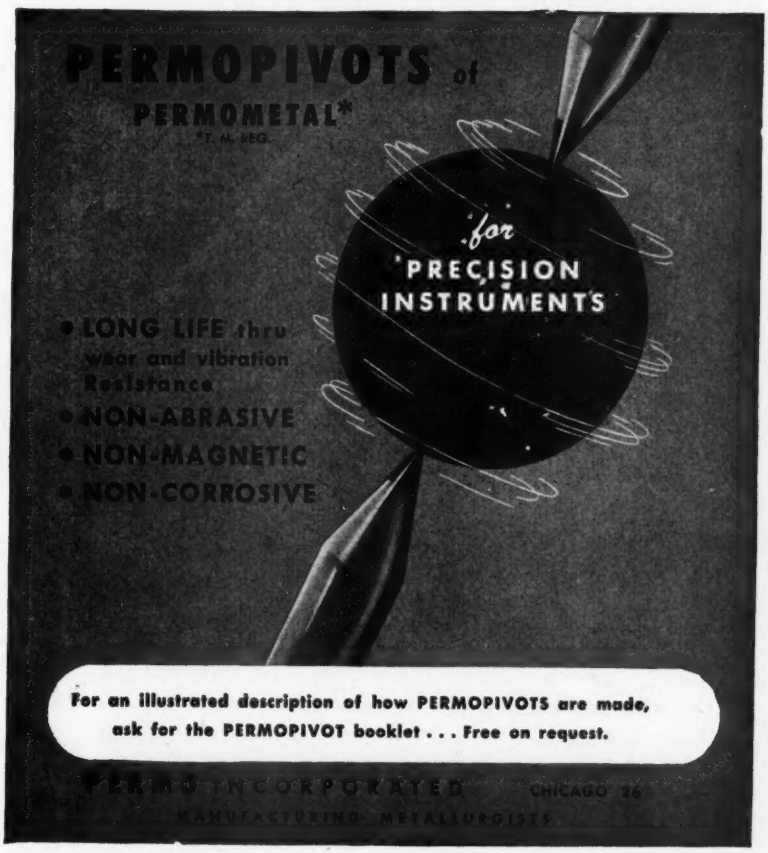

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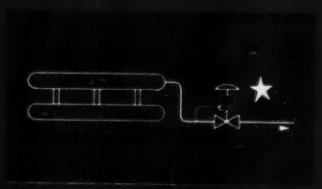

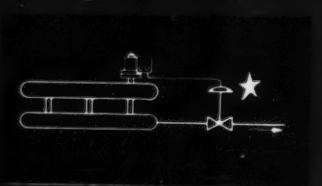

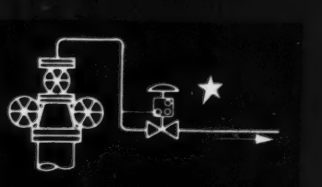

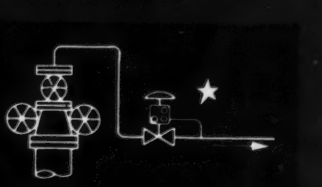

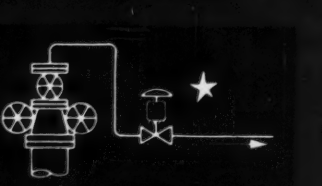

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Measurement *of* Flow *of* Fluids *through* Orifice Meters

with Particular Reference *to the* Measurements *of* Liquids *and* Steam

By WILLIAM L. COWAN, Union Oil Company

This installment concludes Mr. Cowan's article. Previous installments appeared in the July and August issues of the Journal.

Viscosity Units and Conversions

1 Centipoise=viscosity of water at 68 F.=0.000672 lbs./sec. ft.

1 Poise=100 centipoises
=0.0672 lbs./sec. ft.

S=Saybolt Seconds Universal
$=G_{60}T_c(0.0022\ S-1.8/S)\ 0.0672$ lbs./sec. ft.
$=G_{60}T_c(0.0022\ S-1.8/S)$ Poises

Flow Formulas for Steam

If the density of steam is determined from the pressure at the downstream pressure tap, the general flow formula can be obtained from formula (12)' and inserting the F_{e2} factor so that,

$$W=(359.1\,d^2K_o)F_{e2}F_R\sqrt{hw}\ \text{Lbs./Hr.} \quad (25)$$

As F_{e2} and F_R are relatively small, these factors are usually omitted particularly in measurement of steam at high pressures. The values of F_{e2} and F_R given in C.N.G.A. Bulletins TS-353 and TS-402 for gas can be assumed to be approximately the same as for steam if it is found desirable to use them.

The density of steam can be determined directly from steam tables if the steam pressure, degrees of super heat or quality are known.

Density of steam of 100 percent quality can be obtained directly from steam tables if its pressure is known.

Density of wet steam can be found if the pressure and quality are known. Letting w_s=density saturated steam, then density of wet steam of quality (x) equals

$$w=\frac{w_s}{X}\ \text{or}\ X=\frac{w_s}{w}\ \text{or}\ wX=w_s \quad (26)$$

The quality of steam can be determined by steam calorimeter.

Density of superheated steam can be determined from steam tables if its pressure and temperature are known.

In many instances the pressure in steam measurements and steam quality or degrees superheat are relatively constant so that flowing density can be incorporated in the general coefficient and flow then equals this coefficient$\times\sqrt{h}$ giving flow in lbs./hr.

Bellows types of differential gages record the actual differential head (h) so that when these types of gages are used the above formula (25) can be used as shown.

When mercury type recorders are used, an additional correction for the water over the mercury is required as in all steam measurements water seal pots are used and F_M from (23)=

$$F_M=\sqrt{1-1/13.57}=0.9625 \quad (27)$$

For mercury recorders, therefore, this value of F_M can be incorporated in the general flow equation which becomes

$$W=(345.6\,K_o d^2)F_{e2}F_R\sqrt{h'w}\ \text{Lbs./Hr.} \quad (28)$$

A more general method of computation is to set up a set of coefficients based on the density of saturated steam at 114.4 psi. abs. which equals 0.2564 lbs./cu.ft. and compute $\sqrt{w}$ from pressure records and the quality or superheat of steam.

For mercury type recorders, coefficients have been establshed which first assume that the density of steam varies directly with the ratio of

$$\left(\frac{0.2564\times P_2}{114.4}\right)$$

and then additional factors F_P and (F_x or F_{su}) established to correct for this assumption, formula (28) can then be written for mercury recorders as follows:

$$W=(345.6\,K_o d^2)\sqrt{\frac{0.2564\,P_2}{114.4}}\times F_P\times (F_x \text{ or } F_{su})\times F_{e2}F_R\sqrt{h'}\ \text{Lbs./Hr.}$$

$$W=(16.36\,K_o d^2)F_P(F_x \text{ or } F_{su})F_{e2}F_R\sqrt{h'P_2}\ \text{Lbs./Hr.} \quad (29)$$

where

$F_P=\sqrt{(w_s\times 114.4)/(0.2564P_2)}$

where w_s = actual density of saturated steam at P_2 (30)

Where $F_x=\sqrt{w/w_s}$ where w=actual density of wet steam of quality (X) at pressure P_2 (31)

$=\sqrt{1/X}$ where X=steam quality

Where $F_{su}=\sqrt{w/w_s}$ where w=actual density of superheated steam at P_2 (32)

When bellows type differential gages are used, the flow can be obtained by multiplying above mercury gage formulas by factor $(1/0.9625)=1.039$.

As steam is usually measured at a high temperature, the orifice plate expands to a small degree and the diameter of the orifice is slightly enlarged from its value at atmospheric temperature. This condition may also exist when measuring any other fluid at a high temperature. Correction factors for plates of various materials are given for this effect in Pittsburgh Equitable Meter Company's manual, "The Orifice Meter." These published factors represent the ratio of (d^2, at flowing temperature)/(d^2 at 60 F.). The application of this factor becomes of importance above flowing temperature of 150 F. as the average magnitude of this correction factor for the four plate materials shown is 1.0016 at 150 F., and 1.0000 at 60 F. These published factors assume that the diameter of the orifice was measured at a plate temperature of 60 F. If it is measured at a temperature other than 60 F., the correction factor applied should be revised accordingly.

In steam measurement, the pressure to be recorded is the pressure of steam on the steam line at P_2. If a test gage is placed at the recorder the indicated pressure must be corrected for the head of water between the steam pots and the recorder, 1 foot of water head equalling 0.433 psi.

Values of 16.36 $K_o d^2$, 345.6 $K_o d^2$ and 359.1 $K_o d^2$ can be obtained from published tables of $C=338.2\ K_o d^2$ for gases by multiplying these published values of $C=338.2\times K_o d^2$ for gases, by (16.36/338.2), (345.6/338.2) and also obtainable from revised S.C.M.A. Data Sheets

October Meeting: Thursday, the 18th, 1951, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, meeting at 8:00 P.M.

Feature: "Ring Force Balance Meters" by a representative of the Hagan Corporation.

159 and 160. Values of F_p, F_x and F_{su} are given on S.C.M.A. Data Sheet 162.

Calculation of Special Orifice Sizes for Given Flow Conditions

Gas Flow (*see Formula* (18)')

$$Q=(338.2\,K_o d^2)F_{e2}F_R F_G F_T F_{Pv}\sqrt{hP_2}$$

Std. Cu. Ft./Hr. (33)

$K_o d^2=K_o\beta^2 D^2$ and $K_o=K_{o4}L$ and also $K_{o4}=Z/338.2$ (34)

The above general gas formula can then be written

$$K_o\beta^2=Q/(338.2D^2\ F_{e2}\times F_R F_T F_{PV} F_G\sqrt{hP_2}) \quad (35)$$

or

$$K_{o4}\beta^2=Q/(338.2\ LD^2\ F_{e2}\times F_R F_T F_{PV} F_G\sqrt{hP_2}) \quad (36)$$

or

$$338.2K_{o4}\beta^2=Q/(D^2\ L\ F_{e2}\times F_R F_T F_{PV} F_G\sqrt{hP_2})=Z\beta^2 \quad (37)$$

Curves or tables of $K_o\beta^2$ versus β, or $K_{o4}\beta^2$ versus β or $Z\beta^2$ versus β can be made. For a given specified flow condition and differential, quick approximations of orifice size required can be obtained from relation

$$338.2\ K_o d^2=C=Q/(F_G G_T F_{PV}\sqrt{hP_2}) \quad (38)$$

and nearest (d) determined from tables of C for standard sized orifices and pipes. Correction factors LF_eF_R can then be quite accurately determined for this approximate orifice and used in the above equations.

By solving for $K_o\beta^2$, $K_{o4}\beta^2$ or $Z\beta^2$, the value of beta can be obtained directly from tables or curves used. (See formulas 35, 36, 37)

Knowing beta, orifice diameter $d=\beta D$ (39)

Liquid Flow

$$Q=(340.1\ K_o d^2)\ F_M L_G L_T F_R\sqrt{h'}$$

Gals./Hr. at 60 F. (Mercury gage) (40)

$$Q=(338.2\ K_o d^2)\ F_M L_G L_T F_R\sqrt{h'}\times(340.1/338.2)$$

Gals./Hr. at 60 F. (40)'

$$K_o\beta^2=Q/(340.1D^2\times F_M L_G L_T F_R\sqrt{h'}) \quad (41)$$

or

$$K_{o4}\beta^2=Q/(340.1\ LD^2\ F_M L_G L_T F_R\sqrt{h'}) \quad (42)$$

or

$$Z\beta^2=\frac{Q\times 338.2}{D^2 L\ F_M L_G L_T F_R\sqrt{h'}\times 340.1} \quad (43)$$

Obtaining beta from curves or tables, $d=\beta D$

Steam

$$W=345.6\ K_o d^2\ F_e F_R\sqrt{wh'} \quad (44)$$

lbs. per hr. (mercury gage) or

$$=16.36\ K_o d^2\ F_e F_R F_P\ (F_x \text{ or } F_{su})\times\sqrt{h'P_2}$$

lbs. per Hr. (mercury gage)

Solving for $Z\beta^2$ and using the equation for density w

$$Z\beta^2=\frac{W\times 338.2}{D^2 LF_e\ F_R\sqrt{wh'}\times 345.6},$$

obtain β from $Z\beta^2$ curves and solve for $d=\beta D$.

Note: If values of $ZL\beta^2$ are plotted against β for each standard pipe size, (L) would be omitted from equations. Such curves can, however, only be used in computing orifice for standard pipe sizes.

The Use of Special Sealing Liquids and General Requirements for Seal Pot Installations in Orifice Meter Measurements

The use of special sealing liquids at some point between the pressure taps on the flow line and the recording gage is essential when metering the following fluids: Corrosive gases or liquids; liquids containing considerable quantities of entrained gases; gases containing considerable quantities of entrained liquids or gases which are readily condensible when cooled below flow line temperature at flow line pressure; liquids of high viscosity at atmospheric temperature; fluids which react with or cause emulsification of mercury when mercury recording gages are used; liquids containing appreciable amounts of some other liquid which would tend to gradually separate out. In the measurement of steam, water (condensed steam), is always used as the sealing liquid.

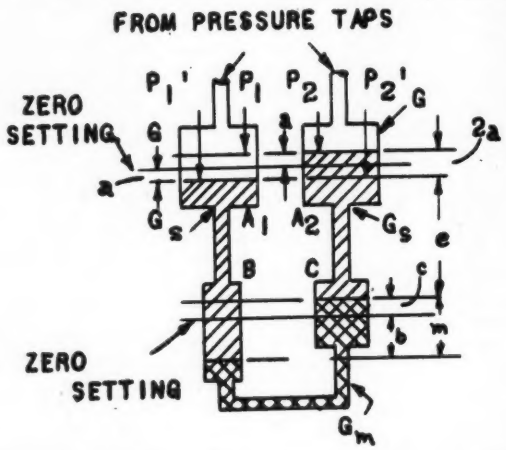


Fig. 5

Ordinarily, water, light oil and gasoline measured at pressures high enough to prevent vaporization can be measured without using special sealing liquids. Such liquids are piped directly to and into the recording gage. Small amounts of entrained vapors or other liquids can be trapped out and vented occasionally by use of special traps on gage line hookup.

The general specifications for a sealing liquid are that it be a liquid which will, (1) not mix with the flowing fluid or contaminate mercury when mercury gages are used, (2) have a specific gravity different than that of flowing fluid, (3) be relatively non-viscous. In most instances water is the most commonly used sealing fluid as it is readily available, cheap and is usually entrained either in a liquid or vaporous state in most of the commonly measured fluids. Water is not desirable if freezing temperatures are expected. Other commonly used sealing fluids are various types of anti-freeze liquids containing anti-rust preventative which should only be used when flowing liquid has no entrained water as most of these liquids mix with water.

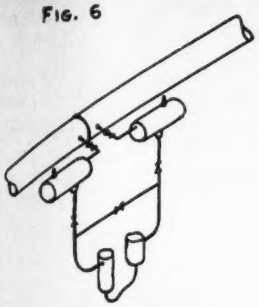
When sealing fluids are used, seal pots or reservoirs are required on both the upstream and downstream gage piping. Both pots should be of the same size and so designed and installed that the level of the sealing fluid in each pot will be equal and remain practically equal from zero to maximum flow. If sealing levels are not held practically equal in both pots, the seal factor given in formula (23) should be computed by special formulas shown later. Seal pots should be carefully leveled and firmly supported so that they will not cause a strain on gage piping.

In the measurement of liquids, gage piping from pressure taps to seal pots (or to recorders when no seal pots are used) should be so installed that there is no possibility of entrapping air, gas or other entrained liquids.

In the measurement of gases containing free liquid and gases which tend to condense, gage piping from pressure taps to seal pots (or to recorders if no seal pots used) should be so installed that any liquids formed will either drain back into the flow line or into special traps installed at low points of the gage line. In measurement of such gases, pressure tap openings should take off at the top of or above the center of a horizontal meter run and slope upwards to seal pots (or to recorder if no seal pots are used). Pressure tap openings should be of maximum allowable size. Gate or plug valves on gage lines are recommended. These same general recommendations also apply to the measurement of steam. For steam measurements, however, pressure tap openings should even be larger than the maximum specified size in order to allow condensed steam to drain back into the meter run. In one particular instance, see Fig. 8, additional water drain lines for condensed water were found to be necessary when measuring an extremely varying flow of steam.

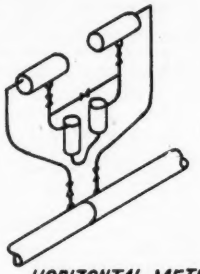
Recommended methods for installing seal pots and gage piping, with reference to meter run and recording gage, are shown on Figs. 6 to 20, for various

FIG. 6



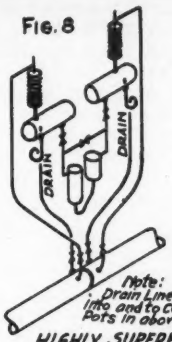
HORIZONTAL METER RUN (GAUGE BELOW)

FIG. 7



HORIZONTAL METER RUN (GAUGE ABOVE)

FIG. 8



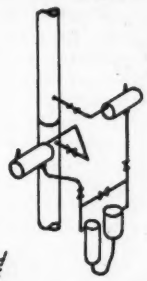
Note: Drain Lines extend into and to center of Pots in above case.

HIGHLY SUPERHEATED STEAM, VARIABLE FLOW

FIG. 9

STEAM POTS

PRESSURE TAPS SHOULD TAKE OFF AT CENTER OF HORIZONTAL RUN OR ABOVE.



VERTICAL METER RUN

GAS WITH LIQUID SEAL

FIG. 10

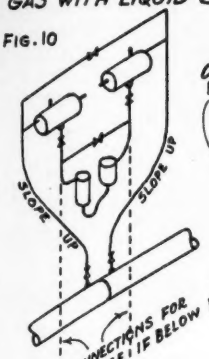


FIG. 11

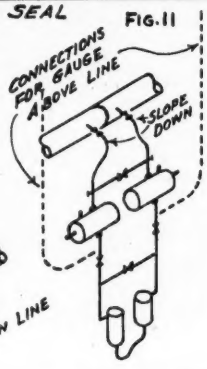
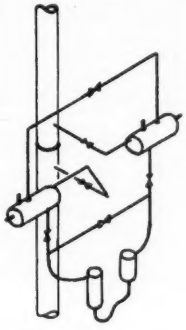


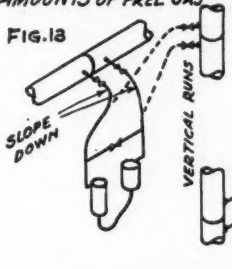
FIG. 12



PRESSURE TAPS SHOULD NOT TAKE OFF BOTTOM OF PIPE.

WATER OR OTHER UNCONTAMINATED, LOW VISCOSITY LIQUIDS CONTAINING ONLY SMALL AMOUNTS OF FREE GAS

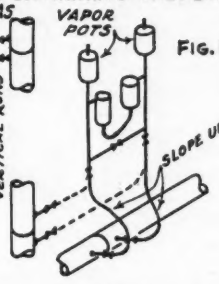
FIG. 13



GAUGE BELOW LINE NO SEAL POT REQUIRED

VAPOR POTS

FIG. 14



GAUGE ABOVE LINE NO SEAL POT REQUIRED

PRESSURE TAPS TAKEN OFF WITHIN 45° OF CENTER OF HORIZONTAL METER RUN.

NON VISCOUS, SLIGHTLY VAPOROUS, LIGHT LIQUIDS HAVING ONLY SMALL FRACTIONS OF ENTRAINED HEAVIER LIQUID. (SPECIAL TRAPS USED)

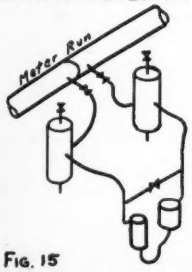


FIG. 15

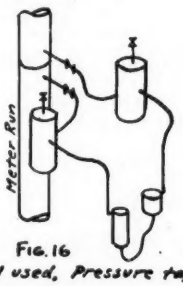


FIG. 16

No special sealing liquid used. Pressure taps and gauge lines sloped down to gauge.

SPECIAL SEALING LIQUID USED (SEALING LIQUID HEAVIER THAN METERED FLUID

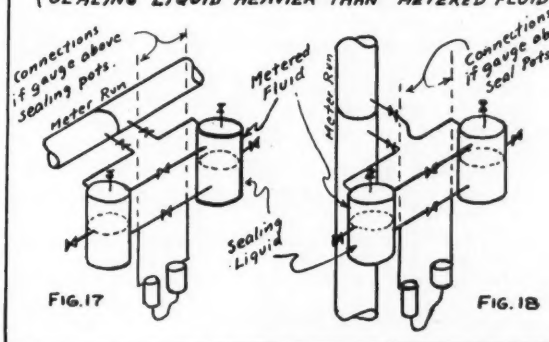


FIG. 17

FIG. 18

SPECIAL SEALING LIQUID USED (SEALING LIQUID LIGHTER THAN METERED LIQUID)

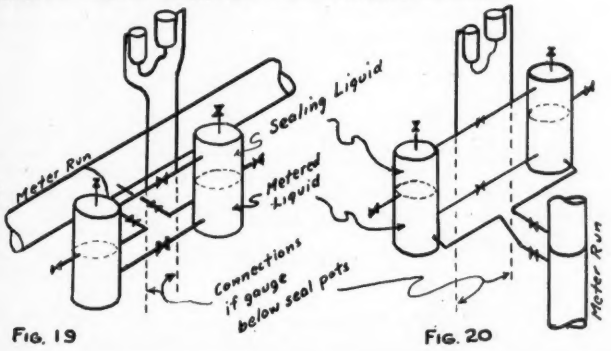


FIG. 19

FIG. 20

GENERAL NOTES ON SEALING POTS.

Place both sealing pots at same elevation.

Seal Pots must be equipped with necessary valves or plugs for filling or venting and for determing sealing fluid levels.

Make size of seal pots such that the change in sealing liquid-metered fluid level is negligible during flow conditions.

Seal pots placed horizontally are generally recommended over vertically installed pots

Sealing fluid-metered fluid levels should be maintained at center of horizontally installed sealing pots.

GENERAL RECOMMENDATIONS FOR INSTALLING SEAL POTS AND RECORDING GAGES

types of fluid measurements. The bypass across the recording gage may be either above or below the instrument.

The temperature gradient per foot of vertical height in gage lines from pressure taps to seal pots (or to recorder when no seal pots are used) should be equal in both the upstream and downstream gage lines. This is particularly a necessary precaution in case pipe taps are used. Flange taps are, however, recommended in every instance. In measurement of hot liquids which may congeal at lower temperatures, it may become necessary to add additional heat to this section of gage piping and even to the seal pots in order to obtain a reliable differential record.

In the measurement of steam, water is always used as the sealing liquid. The size of the pots need not ordinarily be as large as those required in other fluid measurements as the sealing fluid levels in each pot are maintained by the condensation of the steam. Each pot should, however, have a liquid capacity at least double that of the maximum displacement of mercury in each side of the recording gage. In the measurement of rapidly changing steam flow, however, large pots are recommended. In the measurement of superheated steam, the pots should be equipped with radiating fins or auxiliary finned cooling surfaces installed above the sealing pot. Air or other entrained gases may at times collect at the tops of steam gage piping and additional air traps installed at this point may become necessary. Gage piping from water pots to pressure taps as well as pressure tap openings into flow line often plug up and prevent drainage of water back into flow line. These openings and this section of piping should be inspected occasionally and if meter is sluggish this is often the cause of the trouble.

In order to obtain the greatest available benefit from a cylindrical sealing pot, the pots should be installed in the horizontal position as this position provides a greater sealing liquid surface per size of pot. Vertically installed pots if of sufficient size to give a proper sealing fluid surface are often used as they are more easily installed.

The calculation of sealing pot sizes for use in installations, using a mercury type recording gage, is determined as follows: (Note: If bellows type gages are used, the actual displacement of sealing fluid in the upstream and downstream parts of the gage must be known in order to arrive at the corresponding displacement which would occur in the sealing pots.) In the following derivations the sealing pots are assumed as vertical. As the actual allowable vertical change of sealing fluid is small in most cases, change in displacement of sealing fluid in each pot can be closely figured for a horizontal sealing pot if sealing liquid level is at center of pot by the (diam. of pot×length of pot) × (allowable increase in height of sealing liquid level computed for a vertical pot).

In general practice it is desirable to use a manometer factor F_M as specified by equation (23). Seal pots should be made large enough so that by using the above value of F_M, no appreciable error in measurement will result. If the allowable error for instance is 0.5 percent then equate F_1 as obtained from equation 47 or 49, as the case may be, to 1.005 and solve for A from other known values.

Case I. Detailed Calculation of F_M Factors for Sealing Liquid Heavier than Metered Fluid (See Fig. 5) (Assuming Vertical Cylindrical Seal Pots)

Let:

Areas in square inches of

Horizontal Liquid Surface Levels

$A=A_1=A_2$ for each seal pot$=0.7854\ d_a^2$

B=High Pressure Mercury Chamber $=0.7854\ d_b^2$

C=Low Pressure Mercury Chamber $=0.7854\ d_c^2$

Specific Gravities of Fluids (Water =1.0000)

G=Metered Liquid at Seal Pot Temp.

G_s=Sealing Liquid

Note: G_s at pot assumed=G_s in recorder

G_m=Mercury in Recording Gage

Vertical Heights in Inches

a=lowering of metered liquid and sealing liquid level in seal pot A_1 and

a=Rise of metered liquid and sealing liquid level in seal pot A_2

b=Lowering of sealing liquid and mercury level in H.P. pot of gage

c=Rising of sealing liquid and mercury level in L.P. pot of gage.

Expressing Pressures in Inches of Mercury at 60 F. and Volumes in Cu. Inches

Aa=Bb=Cc=Change in displacements of liquids for differential (P_1-P_2) (45)

$b+c=m$ (46)

or $b=m-c$ and from (45) and (46)

$Cc=Bm-Bc$ or

or $c=Bm/(B+C)$ (47)

and from (45) and (47)

$Cc=CBm/(B+C)$ which also equals (Aa) therefore

$$a=\frac{BCm}{A(B+C)} \tag{48}$$

Since the pressure in each leg of the mercury column is equal at a level equal to that of mercury-seal fluid level in pot B

$P_1'+e(G_s/G_m)+m(G_s/G_m)=P_2'+e(G_s/G_m)+m$, from which

$P_1'-P_2'=m(1-G_s/G_m)$ (49)

or $m=(P_1'-P_2')/(1-G_s/G_m)$

Let n=true differential pressure across pressure taps$=(P_1-P_2)$

$P_1=P_1'-2aG/G_m$ and $P_2=P_2'-2aG_s/G_m$ (50)

from which (P_1-P_2) equals

$n=P_1'-P_2'+2a(G_s-G)/G_m$

or from (49) and (50)

$n=m(1-G_s/G_m)+2a(G_s-G)/G_m=$ actual differential in in. mercury. (51)

Since (m) is the actual change in mercury level in the recording gage, it represents the indicated differential pressure. The recorder automatically converts (m) to inches of water or indicated differential h'.

Also $nG_m=h$, the actual differential across pressure taps in inches of water and (mG_m)=indicated differential h'. By multiplying equation (51) by G_m then

$$nG_m=mG_m(1-G_s/G_m)+2a(G_s-G) \tag{52}$$

which also equals

$h=h'(1-G_s/G_m)+2a(G_s-G)=$ (53)

actual pressure drop in inches of water.

In orifice meter flow calculations the $\sqrt{h}$ is required and the correct value of

$\sqrt{h}=F_M\sqrt{h'}$ or $F_M\sqrt{(h/h')}$

or from (41), F_M=correction Factor

$$F_M=\sqrt{(1-G_s/G_m)+(2a/h')(G_s-G)} \tag{54}$$

or

$$F_M=\sqrt{\left(1+\frac{G_s}{G_m}\right)+\frac{2BC(G_s-G)}{AG_m(B+C)}} \tag{55}$$

when (a) is given its value from (48) and (h') made$=(mG_m)$, or

$$F_M=\sqrt{\left(1+\frac{G_s}{G_m}\right)+\frac{2(d_c/d_a)^2(G_s-G)}{G_m\left[1+(d_c/d_b)^2\right]}} \tag{56}$$

when areas pots expressed in pot diameters.

In common practice, the seal factor used equals $\sqrt{1-G_s/G_m}$ and if the degree of error caused by this assumption is called (F_1),

$$F_M=F_1\sqrt{1-G_s/G_m} \quad \text{or} \quad F_1=F_M/\sqrt{1-G_s/G_m} \tag{57}$$

and from (54), (55), (56),

$$F_1=\sqrt{1+\frac{2a(G_s-G)}{h'(1-G_s/G_m)}} \quad \text{or}$$

$$a=(F_1^2-1)\times\frac{h'\times(1-G_s/G_m)}{2(G_s-G)} \tag{58}$$

and also

$$F_1=\sqrt{1+\frac{2BC}{AG_m(B+C)}}\times\frac{(G_s-G)}{(1-G_s/G_m)} \tag{59}$$

$$F_1=\sqrt{1+\frac{2}{G_m}\times\frac{(d_c/d_a)^2(G_s-G)}{\left[1+(d_c/d_b)^2\right]\left[1-G_s/G_m\right]}} \tag{59}$$

From formulas (55), (56), (59), it is apparent that for any one set of pots of areas A, B, C that the correction factors F_M or F_1 are constant for any given values of G_s and G, regardless of flow rate.

Case II. Sealing Liquid Lighter than Metered Liquid

By reasoning similar to that shown above for sealing liquids heavier than metered fluid, the following formulas have been devised for Sealing Liquids lighter than metered fluid.

$$F_M=\sqrt{(1-G_s/G_m)+2a(G-G_s)/h'} \tag{60}$$

and

$$F_1=\sqrt{1+\frac{2a(G-G_s)}{h'(1-G_s/G_m)}} \quad \text{or}$$

$$a=(F_1^2-1)\times h'\frac{(1-G_s/G_m)}{(G-G_s)} \tag{61}$$

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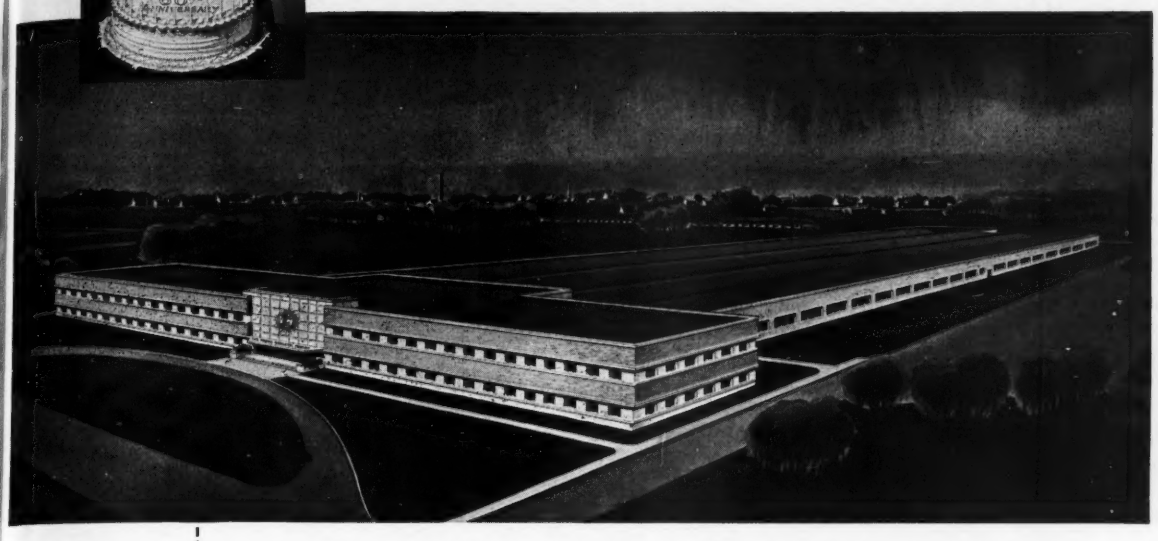

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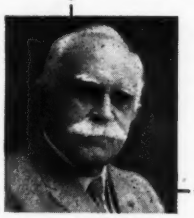

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 1113.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

Temperature

T-668 Potentiometer Temperature Indicators. 16-page Bulletin 305-3 illustrates and describes maker's line of single-point, multiple-point, and portable temperature indicators which use the null-method potentiometer principle.—The Foxboro Co., Foxboro, Mass.

T-669 Temperature Controller. 4-page folder illustrates and describes maker's "Electromax" controller for temperatures up to 1000 F. Includes features and applications.—Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, Penna.

T-670 Pyrometer Controllers. 34-page Catalog No. 1A contains 12 bulletins describing maker's line of "Simplytrol" pyrometer controllers, contact meter relays, and portable pyrometers.—Assembly Products, Inc., Chagrin Falls, Ohio.

T-671 Pyrometer Controller. 4-page Bulletin SJ-1 contains operating and servicing instructions for "Model-J Gardsman" indicating thermocouple-type pyrometer controller.—Taco West Corp., 525 N. Noble St., Chicago, Ill.

T-672 Thermistor Bolometers. 2-page brochures illustrate and describe (1) thermistor bolometers for infrared radiation detection, (2) bolometer preamplifier, (3) thermistor power unit, and (4) radiation pyrometer for remote measurement of temperature.—Servo Corporation of America, 2020 Jericho Turnpike, New Hyde Park, N. Y.

T-673 Spot-cooling Device. 2-page brochure Form V-2-551 illustrates and describes three models of vortex tubes which use compressed gas or air to produce temperature drops.—Thermo Instruments Co., 1168 El Camino Real, Belmont, Calif.

T-674 Test Cabinets. 12-page brochure illustrates and describes maker's line of test chambers which control temperature and humidity. Includes applications in research, testing, etc.—Northern-Zaleski, Ltd., Pratt Oval, Glen Cove, L. I., N. Y.

T-675 Test Cabinets. 4-page brochure illustrates and describes maker's test cabinets for high and low temperatures and controlled humidity.—Standard Cabinet Co., 52 Washington Ave., Carlstadt, N. J.

Pressure

T-676 Vacuum Gage. 2-page Catalog 104 illustrates and describes thermocouple vacuum gage. Includes principles and accessories.—Hastings Instrument Co., Inc., Super Highway and Pine Ave., Hampton, Va.

Flow

T-677 Anemometer. 2-page Catalog 102 illustrates and describes maker's portable thermopile-type "Air-Meter" for measuring air velocities.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

T-678 Thermal Anemometer. 11-page reprint of paper "A Compensated Thermal Anemometer and Flowmeter" discusses theory and design of instrument using thermocouple in airstream.—Hastings Instrument Co., Inc., Hampton, Va.

T-679 Water Meters. 18-page Vol. 35 No. 3 issue of house organ "Water Journal" features articles on water works, sewage treatment, and disc meters.—Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Penna.

Speed

T-680 Tachometer Indicator. 4-page Technical Data Sheet No. 42R describes features of maker's multiple-head single-range tachometer indicator.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

T-681 Speed Changer. Technical Data Sheet No. 4C describes maker's variable-ratio mechanical speed changer with push-rod control.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

Process Controllers

T-682 Recorders and Controllers. 8-page Bulletin 17-C illustrates and describes maker's line of process controllers, components, systems, and indicating-recording-integrating combinations. Includes principles and functions.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

T-683 Meters and Control Systems. 12-page Bulletin No. 15-H illustrates and describes maker's line of controllers, recorders, gages, and valves for power-plant and industrial-process control. Includes principles and applications.—Bailey Meter Co., 1044 Ivanhoe Rd., Cleveland 10, Ohio.

T-684 Flow Ratio Controller. 8-page Catalog 53 illustrates and describes maker's line of "Ratomatic" controllers for proportioning flow of fluids or gases in two or more lines. Includes principles and applications.—Fischer & Porter Co., 4600 County Line Rd., Hatboro, Penna.

T-685 Recorder and Controller. 2-page folder describes features of "Ca-

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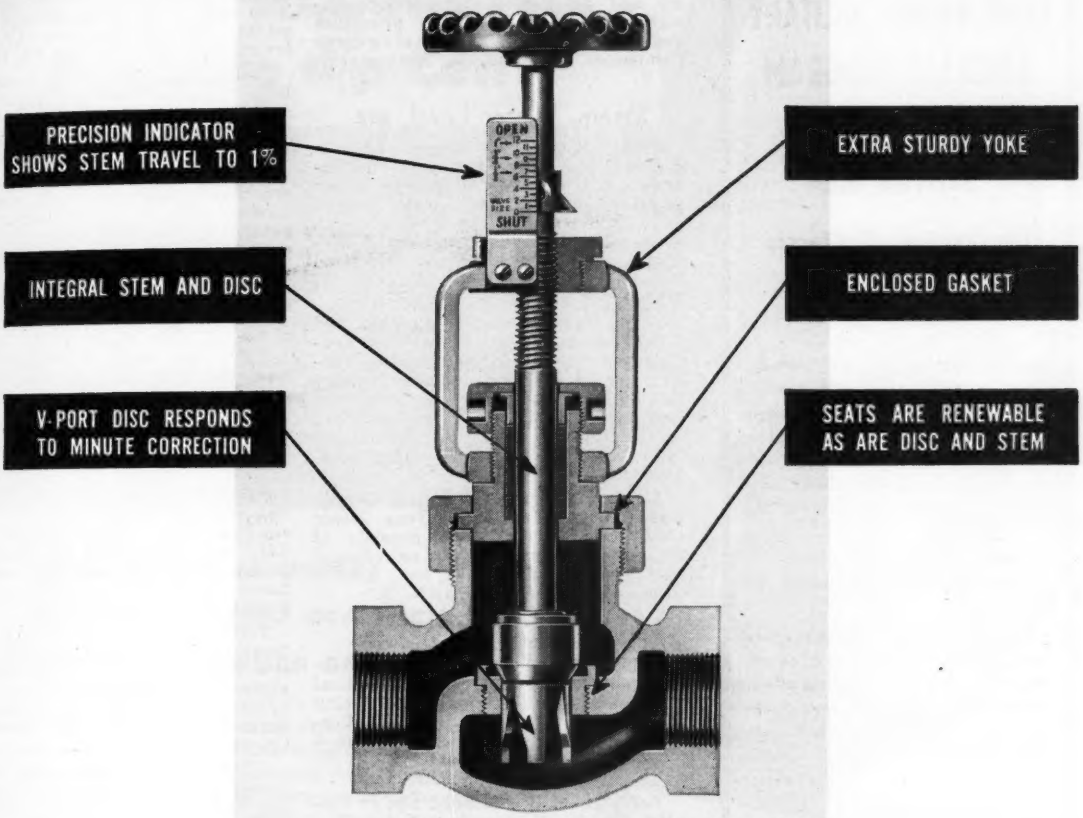
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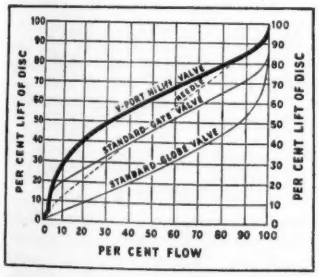
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T-703 **SO_2 Recorder.** 8-page brochure illustrates and describes SO_2 recorder for measuring air pollution. Includes principles and specifications.—Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, Penna.

Electrical and Electronic Instruments

T-704 **Kilovoltmeter.** 1-page Bulletin F-56 describes 100-kv. voltmeter, 25-kv. power supplies, hi-voltage probes, scale-printing machine, micro-circle cutters, and electro-graphic recorder.—Precise Measurements Co., 942 Kings Highway, Brooklyn 23, N. Y.

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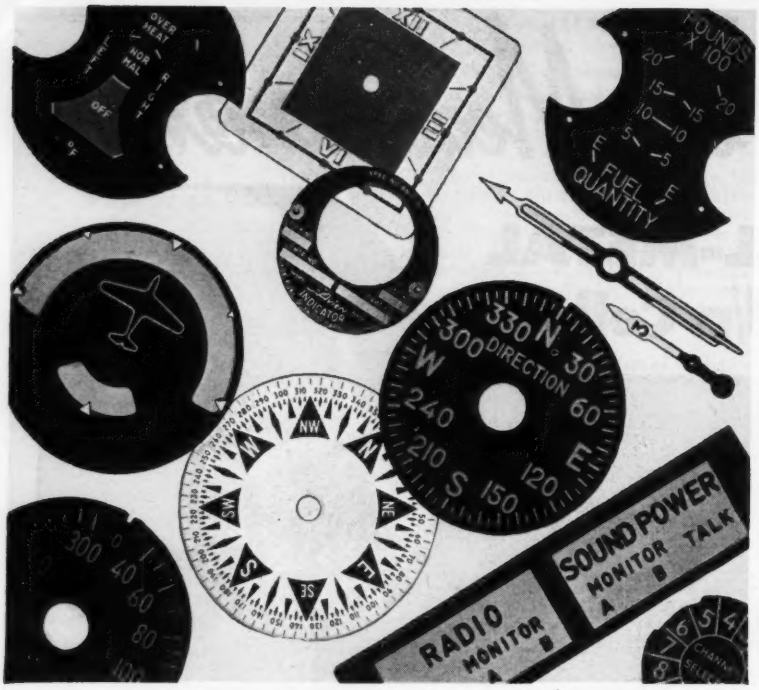

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Electrical and Electronic Instruments Continued

table, switchboard, and panel instruments together with classification and selection information.—Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Penna.

T-707 Signal Generators. 2-page brochures illustrate and describe (1) crystal-controlled generator for 150 kc. to 150 Mc., (2) marker generator for 500 kc. to 32 Mc., and (3) secondary frequency-standard generator for 1 kc. to 85 Mc.—Servo Corporation of America, 2020 Jericho Turnpike, New Hyde Park, N. Y.

T-708 Low-frequency Generator. 4-page Vol. 2 No 10 issue of house organ "hp Journal" illustrates and describes new generator which generates sinoidal, square, or triangular waves from 1000 to 0.01 cps.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

T-709 Tuning-fork Oscillators. 16-page brochure and 13-page supplement illustrates and describes maker's line of tuning-fork oscillators. Includes principles and specifications.—Philamon Laboratories, 5717 Third Ave., Brooklyn 20, N. Y.

T-710 Servoscope. 4-page brochure describes maker's "Servoscope" signal generator for testing response of servosystems.—Servo Corporation of America, 2020 Jericho Turnpike, New Hyde Park, N. Y.

T-711 Oscillograph. 12-page Vol. 1 No. 3 issue of house organ "Engineering News" features articles on use of maker's oscillograph in measuring acceleration and strains.—Hathaway Instrument Co., 1315 S. Clarkson St., Denver 10, Colo.

T-712 Oscilloscope Preamplifier. 12-page Vol. 18 No. 6 issue of house organ "Sylvania News" features articles on an oscilloscope preamplifier, TV raster variations, TV remote viewer, etc.—Sylvania Electric Products, Inc., P. O. Box 431, Emporium, Penna.

T-713 Amplifier-Recorder. 22-page brochure contains 8 bulletins describing maker's recording systems, including galvanometer, amplifiers, and recorder with heat-sensitive paper.—Sanborn Co., 39 Osborn St., Cambridge 39, Mass.

T-714 Wired Television. 16-page Bulletin 1025 illustrates and describes applications of maker's "Utiliscope" television equipment in research, education, industry, protection, etc.—Diamond Power Specialty Corp., Lancaster, Ohio.

T-715 Radiation Counters. Five 2-page bulletins illustrate and describe (1) "Scintiscaler Model CX 14" alpha scintillation counter, (2) "Scintimonitor Model AX10" counting rate meter, (3) "Scintidapter Model AX11" which converts G-M counters to operate with scintillation counters, (4) "Scintimeter Model LAX12" gamma detector, and (5) "Scintilocalizer Model TAX11" gamma detector with directional ports.—R-C Scientific Instrument Co., 335 Culver Blvd., Playa Del Rey, Calif.

T-716 Beta-ray Thickness Gage. 4-page Bulletin BG-1 illustrates and describes maker's "Model BG-1" beta-ray gage for continuous thickness measurement on production lines. In-

cludes features and theory.—Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.

T-717 **Metal Detector.** 20-page Brochure 14B7217A illustrates and describes maker's "Electronic Metal Detector" which safeguards nonmetallic processes from small stray metallic particles. Includes principles and applications.—Allis Chalmers Mfg. Co., Milwaukee 1, Wis.

T-718 **Pickup and Measuring Equipment.** 28-page catalog illustrates and describes maker's "Dynamic Measuring Equipment" which uses variable-inductance pickup for dynamic or static measurement of force, pressure, and acceleration. Includes description of carrier oscillator and coupling unit.—Wiancko Engineering Co., 2670 N. Fair Oaks, Altadena, Calif.

T-719 **Remote Indicator.** 4-page Bulletin Section 6197 illustrates and describes maker's d-c. operated remote indicator and control equipment, consisting of transmitter and synchro-type receiver.—Allis Chalmers Mfg. Co., Milwaukee, Wis.

T-720 **Power Supplies and Oscillators.** 8-page Vol. 26 No. 2 issue of house organ "The General Radio Experimenter" illustrates and describes unit power supplies and unit two-frequency oscillators. Also article on u-h-f. harmonic generation by crystal diodes.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-721 **Feeder Voltage Regulators.** 12-page Vol. 17 No. 2 issue of house organ "Maintenance News" features articles on maintenance of induction-type and step-type feeder voltage regulators, and industrial plant lighting.—Westinghouse Electric Corp., East Pittsburgh, Penna.

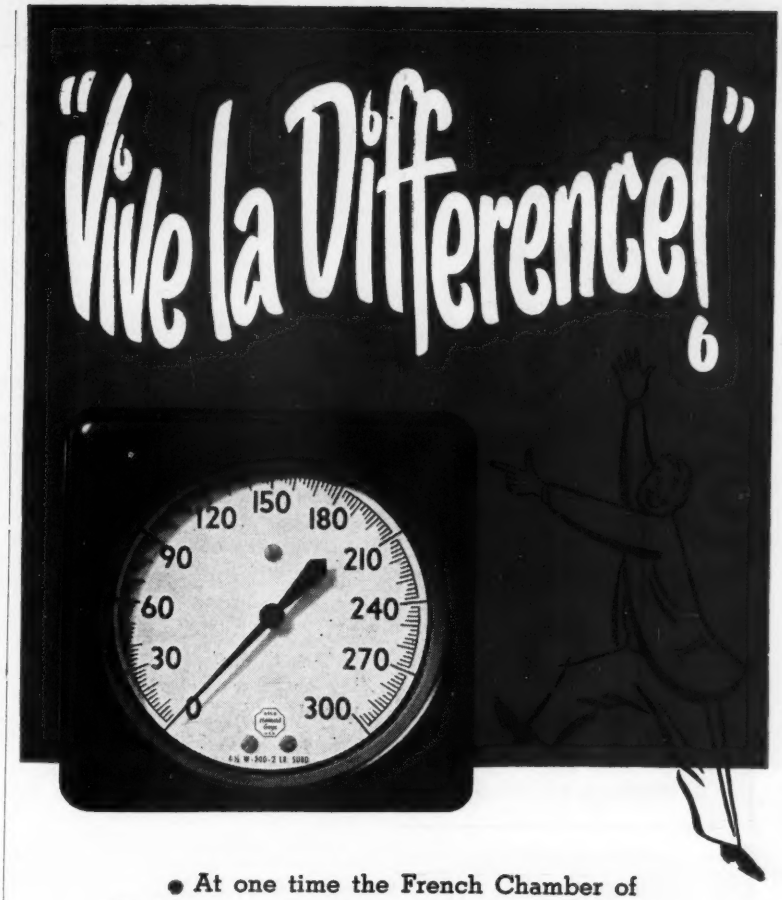
T-722 **Three-component Accelerometer.** 4-page brochure illustrates and describes characteristics and applications of a pendulum accelerometer which records accelerations in 3 perpendicular directions.—Vibration Specialty Co., 1536 Winter St., Philadelphia 2, Penna.

T-723 **Tri-dimensional Vibrograph.** 4-page brochure describes (1) a seismographic-type vibrograph which records vibrations in 3 mutually perpendicular directions and (2) a vibrometer which performs same functions but with visual indication only.—Vibration Specialty Co., 1534 Winter St., Philadelphia 2, Penna.

T-724 **Decade Resistor.** 8-page Vol. 26 No. 1 issue of "The General Radio Experimenter" illustrates and describes (1) new "Type 1432" decade resistors in 3-, 4-, and 5-decade boxes, and (2) multirange filter for audio and ultrasonic amplifiers.—General Radio Co., Cambridge, Mass.

T-725 **Servomechanism Operation.** 20-page Bulletin S-3 "Multiple Mode Operation of Servomechanisms" gives mathematical theory and "phase-portrait" responses of closed-loop servomechanisms. Explains modes of operation and application of multiple-mode operation.—Cook Research Laboratories, Cook Electric Co., Chicago 14, Ill.

T-726 **Carrier Telephone System.** 4-page brochure Form 33A-P4 illustrates and describes new "Type 33A" 3-channel single-sideband carrier tele-



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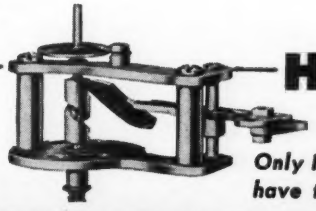

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phone system.—Lenkurt Electric Co., County Rd., San Carlos, Calif.

T-727 **Carrier-system Dialing Auxiliary.** 8-page Form HI-D-P10 illustrates and describes electronic auxiliary which provides dial signalling on carrier communication systems. Includes theory and characteristics.—Lenkurt Electric Co., San Carlos, Calif.

Electrical and Electronic Components

T-728 **Mica Capacitors.** 60-page combined Catalog 420 & Faradon Catalog 421 illustrates and describes maker's large line of mica capacitors for industry and commerce. Includes electrical, physical, and application data.—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

T-729 **Capacitors and Switch.** Technical bulletins describe (1) ceramic-button capacitors, (2) ceramic transmitting capacitors, and (3) lever switch.—Centralab, Division of Globe-Union, Inc., 900 E. Keefe Ave., Milwaukee 1, Wis.

T-730 **Capacitors and Vibrators.** 16-page Vol. 16 No. 7 issue of house organ "The CD Capacitor" features article on "Servicing Video Amplifier," the "Radio Trading Post," and descriptions of maker's capacitors and vibrators.—Cornell-Dubilier Electric Corp., Hamilton, Blvd., South Plainfield, N. J.

T-731 **Electronic Components.** 23-page indexed Catalog 151 illustrates and describes maker's line of hundreds of components—racks, chassis, capacitors, chokes, connectors, insulators, switches, dials, pilot lights, etc.—Bud Radio, Inc., 2118 E. 55th St., Cleveland 3, Ohio.

T-732 **Transformers.** 10-page Catalog 5111 indexes, illustrates, and describes maker's line of transformers, including filter chokes and blocking-oscillators, driver, interstage, modulation, output, plate, power, matching, isolation, and vibrator transformers.—Merit Transformer Corp., 4427 N. Clark St., Chicago 40, Ill.

T-733 **Electronic Instruments and Components.** 162-page Catalog No. 51 (1951) illustrates and describes complete line of electronic instruments, accessories, components, etc., handled by wholesale organization.—Newark Electric Co., 323 W. Madison St., Chicago 6, Ill.

T-734 **Vacuum and Gas Tubes.** 16-page Catalog 86-020 classifies, illustrates, and describes line of Westinghouse phototubes, Pliotrons, Thyratrons, Ignitrons, Kenotrons, Phanotrons, and voltage regulators handled by representative.—Milo Radio & Electronics Corp., 200 Greenwich St., New York 7, N. Y.

T-735 **Connectors.** 4-page Vol. 4 No. 6 issue of house organ "Engineering News" describes (1) use of maker's connectors in oscilloscope and (2) TV antenna rotator.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

T-736 **Snap-action Switches.** 4-page Bulletin No. 54 illustrates, describes, classifies, and indexes maker's line of 5,000 snap-action switches and actuators.—Micro Switch, Freeport, Ill.

T-737 **Mercury Switches.** 4-page Catalog Hg-1 illustrates and describes maker's line of mercury switches. Includes selection aids, application aids, and specifications.—Micro Switch, Div. Minneapolis-Honeywell Regulator Co., Freeport, Ill.

T-738 **Plug-in Chassis.** 2-page brochure illustrates and describes maker's "Cinema 8862 Series" chassis in kit form. Includes built-in open-leaf spring-type connectors for plug-in feature.—Cinema Engineering Co., 1510 West Verdugo Ave., Burbank, Calif.

T-739 **Servo Components.** 2-page brochures illustrate and describe (1) "Servoboard" for rapid experimental synthesis of servosystems, (2) 60-cycle servoamplifier, (3) servo laboratory analysis and synthesis equipment, and (4) reluctance servoamplifiers.—Servo Corporation of America, 2020 Jericho Turnpike, New Hyde Park, New York.

T-740 **Crystal Diodes.** 36-page booklet illustrates and describes 24 applications of crystal diodes in interval timers, inductive-kick quenchers, various controller circuits, etc.—Sylvania Electric Products, Inc., Electronics Div., 1740 Broadway, New York 19, N. Y.

T-741 **Printed Circuits.** 2-page technical bulletins illustrate and describe printed circuits for (1) 3-stage amplifiers, (2) i-f. filter, (3) audio-detector plate, (4) coupling circuits, and (5) TV vertical integrator network.—Centralab, Division of Globe-Union, Inc., 900 E. Keefe Ave., Milwaukee 1, Wis.

T-742 **Primary Element.** 10-page booklet illustrates and describes an electromechanical transducer which uses a wire vibrating in a magnetic field. Includes principles and applications.—Rahm Instruments, Inc., 12 West Broadway, New York 7, N. Y.

T-743 **Strain Gages.** 4-page booklet illustrates and describes use of "SR-4" strain gages for industrial weighing, including crane hooks, multi-tank and batch control, conveyor-belt weighing, and axle scale for highway weight checking.—Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.

T-744 **Motors.** 4-page "Condensed Price List" gives prices and data on maker's line of squirrel-cage induction motors, wound-rotor induction motors, d-c. motors, single-phase motors, and controls.—Century Electric Co., 1806 Pine St., St. Louis 3, Mo.

T-745 **Permanent Magnets.** 16-page Catalog No. 11 illustrates and describes maker's line of "Hyflux Alnico V" cast magnets.—The Indiana Steel Products Co., Valparaiso, Ind.

T-746 **Loudspeakers.** 24-page June issue of house organ "Successful Servicing" features article on matching loudspeakers.—John F. Rider Publisher, Inc., 480 Canal St., New York 13, N. Y.

Valves, Piping, Tubing

T-747 **Valves.** 4-page folder illustrates and describes maker's line of diaphragm-motor and hand-operated valves, "Mastertrol" cycle controllers and "Robotron" cycle controllers.—Emmett Machine & Mfg. Co., Inc., 2249 Fourteenth St., S.W., Akron 14, Ohio.

T-748 **Valves.** 4-page Bulletin 510 illustrates and describes maker's line of rotating-disc valves designed to actuate air or hydraulic cylinders. Includes circuits, models, and specifications.—Ledeen Mfg. Co., 1600 S. San Pedro St., Los Angeles 15, Calif.

T-749 **Valve Actuators.** 4-page Bulletin 512 illustrates and describes maker's cylinder-type valve positioners which operate on air, oil, water, gas, or steam. Includes features and applications.—Ledeen Mfg. Co., 1600 S. San Pedro St., Los Angeles 15, Calif.

T-750 **Safety-relief Valves.** 34-page Manual 51-B illustrates and describes principles of manifold discharge piping systems with safety-relief valves which compensate for back-pressure effects.—Farris Engineering Corp., 610 Commercial Ave., Palisades Park, N. J.

T-751 **Alloy-steel Tubing.** 4-page Technical Data Card 149 describes low-carbon, carburizing steels for tubing. Includes data on micro-structure, alloy elements, thermal treatment, etc.—Babcock & Wilcox Tube Co., Beaver Falls, Penna.

T-752 **Seamless Tubing.** 8-page booklet, "High-strength Seamless Tubing to Close Tolerances" describes maker's method for producing precision tubing of various metals, bores, etc.—Tube Reducing Corp., Wallington, N. J.

Materials

T-753 **Ductile Iron.** 8-page Vol. 4 No. 5 issue of house organ "Nickel Topics" features description of "ductile iron", including properties and applications.—The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

T-754 **Plexiglas.** 22-page Vol. IX No. 3 issue of "The Rohm & Haas Reporter" features articles on use of Plexiglas, fabric manufacture and others.—Rohm & Haas Co., Philadelphia 5, Penna.

T-755 **Aluminum.** 8-page July issue of "Alcoa Aluminum News-Letter" features article on use of aluminum tanks, carry-alls, etc.—Aluminum Company of America, Pittsburgh 19, Penna.

T-756 **Beryllium Copper.** 8-page brochure describes properties, finishing, and joining practice of beryllium copper for springs and stampings.—Lee Mechanical Laboratories, 30 Main St., Brooklyn 1, N. Y.

T-757 **Cork.** 4-page brochure 1h/D illustrates and describes characteristics and uses for cork compositions and natural cork. Includes tables of properties, sizes, and specifications.—Dodge Cork Co., Inc., Lancaster 19, Penna.

T-758 **Electroplating.** 4-page bulle-

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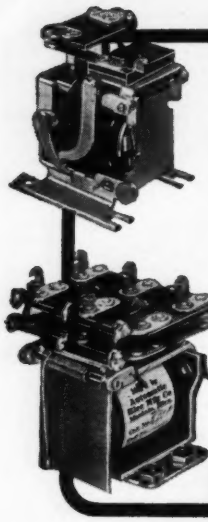

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T-759 **Corrosion of Copper and Copper Alloys.** 24-page Booklet B-36 "Corrosion Resistance of Copper and Copper Alloys" explains nature of corrosive attacks and tabulates resistance of copper and brass alloys to 183 corroding agents.—The American Brass Co., Waterbury 20, Conn.

Weight Control

T-760 **Weight Feeders and Conveyors.** 86-page Catalog 830 illustrates and describes maker's line of vibrating feeders and conveyors, and "Waytrol" gravimetric weight-controlled feeder. —The Jeffrey Mfg. Co., Columbus 16, Ohio.

Instrument Shop Equipment

T-761 **Instrument-shop Table Stove.** 1-page brochure illustrates and describes maker's electric table range with two burners and five heat combinations.—Dominion Electric Corp., Mansfield, Ohio.

T-762 **Arctangent Graph Paper.** 4-page brochure describes principles and applications of arctangent coordinate graph paper with double or single arctangent coordinates. Free samples.—Orbit Electric Co., 2710 N. Menard Ave., Chicago 39, Ill.

T-763 **Meter Houses.** 16-page Catalog No. 4 illustrates and describes maker's line of protective weatherproof meter houses, mercury protectors, safety heaters, fire houses, gate-valve boxes, exhaust jackets, etc.—Moran Furnace & Sheet Metal Co., 807 E. Fifth Place, Tulsa 10, Okla.

T-764 **Battery Charger.** 4-page Bulletin 11-220 illustrates and describes maker's motor-generator battery charger.—The Electric Products Co., 1725 Clarkstone Rd., Cleveland 12, Ohio.

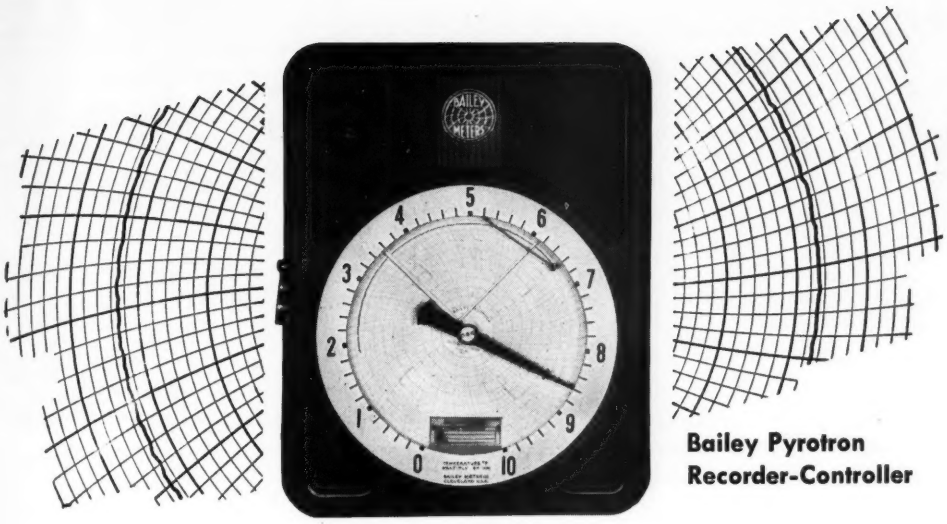
T-765 **Cutting Tools.** 4-page Bulletin 101 illustrates and describes "Crobalt" cast alloy cutting tools. Includes description of best working conditions for various cutting materials.—Crobalt, Inc., 2800 S. State St., Ann Arbor, Mich.

T-766 **Gages.** 50-page Catalog No. 51 illustrates and describes maker's standard gages—thread, plug, and ring. Includes principles, sizes, and prices. —Republic Gage Co., 2228 Fenkell Ave., Detroit 21, Mich.

Miscellaneous

T-767 **Agency Index.** 6-page index lists manufacturers represented by agency. Products are indexed also, including precision tools and diamond products.—R. P. Gallien, 220 W. 5th St., Los Angeles 13, Calif.

T-768 **Centennial Issue.** 40-page Centennial Issue, Vol. 3 No. 4, of house organ "Taylor Technology" illustrates and describes 100 years' growth of company. Includes facilities, quality control, and world-wide markets.—Taylor Instruments Companies, 95 Ames St., Rochester, N. Y.



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